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Rio Blanco Oil Shale Project

FINAL ENVIRONMENTAL BASELINE REPORT FOR TRACT C-a AND VICINITY

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Gulf Oil Corporation—Standard Oil Company (Indiana)

May, 1977

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RIO BLANCO OIL SHALE PROJECT

FINAL ENVIRONMENTAL BASELINE REPORT FOR TRACT C-a AND VICINITY

SECTION 1 CLIMATOLOGY AND AIR QUALITY

SECTION 2 AQUATIC RESOURCES

SECTION 3 TERRESTRIAL ECOLOGY

SECTION 4 PHYSICAL AND BIOLOGICAL INTERACTIONS

SECTION 5 CULTURAL RESOURCES

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APPENDIX

Submitted To Area Oil Shale Supervisor,
Geological Survey, U.S. Department of the Interior,
Pursuant To No. C-20046

Gulf Oil Corporation — Standard Oil Company (Indiana)
May, 1977

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FOREWORD

Information presented herein represents the summation two-years of extensive environmental baseline studies for Tract C-a oil shale tract in northwestern Colorado. This report is supported by a large number of previously submitted documents, including ten quarterly progress reports and two annual summaries. All of these documents are on file with the Area Oil Shale Supervisor in Grand Junction, Colorado and can be examined upon request.

Exploratory activities and baseline studies were conducted in accordance with the "Tract C-a Oil Shale Lease and Environmental Stipulations" as issued by the United States Department of Interior on February 5, 1974 and as amended by subsequent "Conditions of Approval". Immediately following award of the lease, Gulf Oil Corporation and Standard Oil Company (Indiana) submitted a "Preliminary Development Plan" which described planning objectives of the two companies for the development of Tract C-a.

This was followed in May 1974 by an "Exploratory Plan" as required by Section 10d of the lease. This document detailed the plans of Gulf and Standard for obtaining environmental baseline data, establishing monitoring plans, and aquiring geotechnical data for input into mining, processing, and environmental protection design.

Detailed descriptions of objectives, methods, and scheduling of environmental baseline studies were prepared by each individual contractor and submitted late in 1974 as scopes-of-work. These scopes-of-work for each discipline area, as amended and agreed to by the Area Oil Shale Supervisor are on file in the Grand Junction Office.

Data collected during the baseline period were submitted each quarter in conjunction with descriptive information on trends and conclusions observed during the period. RBOSP Progress Reports 1 through 10 and accompanying summary volumes are also on file in Grand Junction. Persons interested in examining data sets from which conclusions for the final report were drawn are referred to these reports.

Following the first year of baseline studies, trends and conclusions for terrestrial and aquatic ecological studies were presented as annual reports. These reports, dated March 1976, also present complete descriptions of program objectives and data accumulation methods. Persons interested in the application of technical methods on Tract C-a should consult these two reports.

Cultural resource surveys in the study area are described in RBOSP quarterly progress reports. A comprehensive report on the cultural resources of the area, submitted in October 1976, is also on file with the Area Oil Shale Supervisor.

Analysis of two years baseline data for the preparation of the final report resulted in the generation of many pages of support documentation. Over 3,000 pages of documentation were generated for hydrology studies alone. This documentation, consisting of computer runs and descriptions of statistical analyses, is presented in RBOSP Progress Report 10.

In addition, the in-depth interpretation, supporting analyses, and graphical representations of terrestrial baseline data are presented in RBOSP Progress Report 10. Other materials presented in Progress Report 10 include support material for aquatic studies and sediment studies, and atmospheric data.

The tenth progress report also contains the cause-effect, measurability, and interactions matrices generated for the purposes of identifying impacts of proposed tract development on the environment, selecting monitoring parameters, and identifying important physical and biological interactions for the study area. These matrices are accompanied by descriptive text materials.

Maintenance of clarity and brevity of the Final Environmental Baseline Report required omission of a great deal of specific information. Some readers may object to this approach when they fail to find items of special interest to them. However, we feel that the approach taken herein was the only feasible means of satisfactorily representing the massive amount of information gained through the study efforts.

INTRODUCTION

This final environmental baseline report presents a description of the environment and wildlife on and near oil shale lease Tract C-a prior to commencement of oil shale development operations. Tract C-a is one of two prototype oil shale lease development areas in northwestern Colorado. Proposed development areas (as well as two in Utah) are located on public land managed by the Bureau of Land Management (BLM), United States Department of Interior (USDI).

The Tract C-a project, better known as the Rio Blanco Oil Shale Project (RBOSP) is the outgrowth of a Department of Interior decision to encourage the development of oil shale reserves on public land in the west by placing selected reserves on public auction as prototype development areas. Lease sales were preceded by informational core drilling by interested private firms to determine the extent of the resources in the area. Once drilling was complete, the USDI offered six tracts (two in Colorado, two in Utah and two in Wyoming) for lease. Tract C-a was placed on auction first. Gulf Oil Corporation and Standard Oil Company (Indiana) jointly offered the highest bid for Tract C-a in January 1974.

Development of Tract C-a is strictly regulated by the terms of the oil shale lease (Serial No. C-20046) issued to Gulf and Standard in February 1974 by the BLM. The environmental stipulation of this lease required the lessee (Gulf and Standard) to conduct a two-year integrated environmental baseline study of the total ecology of Tract C-a to provide an understanding of the basic ecological interrelationships important for successful environmental protection and to allow identification of ecological parameters important for monitoring.

In compliance with this stipulation, Gulf and Standard (RBOSP) engaged the services of Limnetics, Incorporated, of Milwaukee, Wisconsin to manage their environmental programs. RBOSP subsequently engaged the services of EG & G Corporation, Waltham, Massachusetts to conduct meteorology studies. Ecology Consultants, Inc., Ft Collins, Colorado to conduct terrestrial studies, NUS Corporation, Denver, Colorado to conduct aquatic studies and Dr. Alan Olson, University of Denver to conduct cultural resource studies. Later Mr. Steven Baker, Montrose, Colorado, and Dr. Paul O. McGrew, University of

Wyoming were brought in to assess historic and paleontologic resources of the area. Wright Water Engineers, Denver, Colorado was engaged to conduct hydrology studies and the Colorado School of Mines conducted soils studies.

Terrestrial hydrology and aquatic baseline studies were initiated in October 1974. Air studies began in February 1975. Cultural resource studies were conducted during 1975 and 1976.

On September 1, 1976, Gulf and Standard suspended their operations on Tract C-a, with the exception of environmental studies, which were continued through completion. The suspension period is effective until September 1, 1977. During this suspension period, RBOSP engaged NUS Corporation to conduct interim monitoring studies and to complete a detailed analyses of baseline environmental data. These analyses were conducted in order to identify with greater resolution, the ecology of the study area. The results of these analyses and original baseline interpretations are presented in this final report on the environment of Tract C-a and vicinity.

The report contains six sections as follows:

- Section I - Climate and Air Quality
- Section II - Aquatic Resources
- Section III - Terrestrial Ecology
- Section IV - Physical and Biological Interactions
- Section V - Cultural Resources
- Section VI - Revegetation

Each section contains several chapters which present the baseline results by discipline area. Appendices containing the data analysis support material are too lengthy to present here. Therefore, these materials have been submitted in RBOSP Progress 10, May 1977. In addition, the base report for the terrestrial ecological studies for Tract C-a is presented in its entirety with accompanying maps in RBOSP Progress Report 10. Information on the contents of the base report is provided as an appendix to this report for the reader's information.

SECTION 1

CLIMATOLOGY AND AIR QUALITY

SECTION I - CLIMATOLOGY AND AIR QUALITY

PREFACE

A baseline atmospheric program has been carried out for two baseline years, February 1975 to January 1977, to:

- Satisfy the Oil Shale Lease Stipulations, 1974, amended June 1976, and other federal and state regulations;
- Provide site specific information required in developing design criteria for air quality control;
- Provide pre-development values of atmospheric parameters for project impact assessment;
- Provide local meteorological data required for ecological, hydrological, and water quality assessments; and
- Provide local information to verify/correlate existing data and prediction techniques.

In compliance with the oil shale lease requirements, the central station (Site 1) of the monitoring network is located within 3 km of the proposed plant site and at the anticipated point of maximum air quality impact. Three remote stations are located at Sites 2, 3, and 4 to monitor meteorological and air quality parameters throughout the project area.

ABSTRACT

In this section of the Rio Blanco Oil Shale Project (RBOSP) Final Report, the baseline (existing) values of meteorological and air quality parameters are evaluated and the results set forth in visual summaries for quick reference. In addition, the provisions of pertinent rules and regulations of the federal and state governments are reviewed in relation to atmospheric baseline values for potential impact on the further progress of the RBOSP proposed activity at Tract C-a.

The objective of the air quality and meteorology portions of the overall study is to determine, in a scientifically sound manner, the baseline values for various air quality and meteorological parameters. A corollary objective is to identify any existing or potential atmospheric environmental problems which could be exacerbated by the construction and operation of an oil shale facility in the Rio Blanco area.

The detailed objectives of the baseline meteorology and air quality studies are to:

- Define the existing atmospheric environment as a baseline against which to compare future measurements;
- Define meteorological factors which will influence the transport and diffusion of pollutants which might be emitted by sources on or near Tract C-a;
- Identify and quantify the meteorology and air quality of the area for detailed planning purposes.

CHAPTER 1 - GENERAL CLIMATOLOGY

I. REGIONAL DATA

The State of Colorado has two distinct geographical and climatic zones. Consider Interstate Highway 25, which runs north-south through the cities of Denver, Colorado Springs, and Pueblo, as the approximate dividing line between these two areas. Interstate Highway 25 corresponds roughly to Longitude line 105 west (see Figure 1.1). The eastern 40 percent of the state lies in the High Plains regime and is characterized by flat, almost undifferentiated terrain which slopes downward to the east and has a strongly continental-type climate. The western 60 percent of the state is mountainous and experiences more variability in weather parameters because of changes in elevation and exposure which can occur in a short horizontal distance.

The publication "Climatological Data for Colorado, Annual Summary, 1976" was not available when this report was prepared. Climatological data that were accessible have been used.

There are two primary air quality regions whose regulatory criteria apply to Tract C-a. They are mentioned here in order to assist in describing which Colorado climatological data sources from National Weather Service (NWS) are relevant to this discussion. These areas are called Yampa Intrastate Air Quality Control Region (AQCR), and the Oil Shale Interstate Air Quality Maintenance Area (AQMA) (Figure 1.1). These areas and their implications to baseline data are discussed in detail in Chapter 4.

Within the area encompassed by the Yampa Intrastate AQCR there were 33 National Weather Service Stations operating in 1975. Table 1.1 identifies these stations and their respective type and years of record. The geographical locations of these stations are illustrated in Figure 1.1.

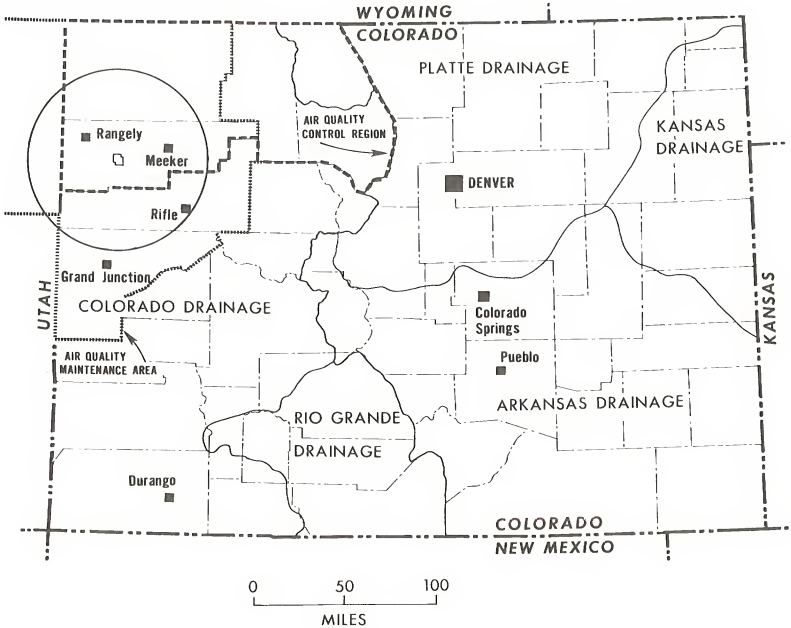

FIGURE 1.1

YAMPA INTRASTATE AQCR, THE OIL SHALE AQMA (COLORADO PORTION), AND A 50-MILE RADIUS OF TRACT C-a

TABLE 1.1

NATIONAL WEATHER SERVICE STATIONS WITHIN THE YAMPA INTRASTATE AIR QUALITY CONTROL REGION, AS OF 1975, RBOSP

County Name	No. of Stations	Location (see Figure 1.1)	Station Type[a]	Years of Record[b]		
Grand	9	Arapaho Ridge	S	NA		
		Berthoud Pass	1,2,3	T: 13;	P: 13;	E: --
		Fraser (closed Oct 75)	1,2,3	62	66	--
		Grand Lake, 1 mile northwest	1,2,3	32	43	--
		Grand Lake, 6 miles south-southwest	1,2,3,4,C	26	26	25
		Hot Sulphur Springs 2 miles southwest	1,2,3,C	22	24	--
		Kremmling	1,2,3	12	12	--
		Parshall, 10 miles south-southeast (closed April 75)	2	--	23	--
		Winter Park	2	--	32	--
Jackson	7	Agua Fria	S	NA		
		Buffalo Park, 1 mile north (closed April 75)	S	NA		
		Flattop Mtn, 3 miles southeast	S	NA		
		Spicer	1,2,3	48	63	--
		Summit Lake, 1 mile east	S	NA		
		Twisty Park	S	NA		
		Walden	1,2,3	39	39	--
Routt	6	Columbine	S	NA		
		Hayden	1,2,3	50	56	--
		Pyramid	2	--	35	--
		Rabbit Ears Pass, 6 miles west-southwest	S	NA		
		Steamboat Springs	1,2,3	63	71	--
		Yampa	1,2,3	12	38	--
Moffat	6*	Browns Park Refuge	1,2,3	10	10	--
		Craig (inactive)	1,2,3,C	37	38	--
		Dinosaur Natl Monument	1,2,3,C	13	26	--
		Great Divide 8 miles southeast (inactive)	C	NA		
		Hamilton	2	--	28	--
		Maybell (inactive)	1,2,3	17	17	--

TABLE 1.1 (Continued)

County Name	No. of Stations	Location (see Figure 1.1)	Station Type[a]	Years of Record[b]		
Rio Blanco	5*	Cliff Lakes	S	NA		
		Little Hills	1,2,3	T: 27;	P: 29;	E: --
		Marvine Ranch	1,2,3	4	4	--
		Meeker No. 2	1,2,3,C	6	6	--
		Rangely	1,2,3	28	35	--

*These stations are also included in the Oil Shale AQMA (see below).

[a]Station types are as follows:

"1" = average temperature and departure from normal
"2" = total precipitation and departure from normal
"3" = temperature extremes and freeze data
"4" = total evaporation and wind movement
"C" = recording rain gage station
"S" = storage precipitation station

[b]Years of Record are shown for temperature, precipitation, and evaporation. When a station was opened or closed during the year, the month of the action is shown. "Inactive" means that the station is closed indefinitely, but in some cases data were reported from it during the year.

The Colorado portion of the Colorado-Utah Oil Shale Interstate AQMA includes an additional 15 stations that lie outside of the Yampa Intrastate AQCR and that were operational during 1975. These stations and their record histories are listed in Table 1.2. Of these 48 observing stations, 11 (those situated in Moffat and Rio Blanco counties) are in both the AQCR and the AQMA. There are 15 stations within approximately 50 miles of RBOSP Tract C-a. They are shown in Figure 1.1. With the exception of the stations in Jackson County and Arapaho Ridge in Grand County, all stations are within the Colorado River Drainage Basin.

During 1975, the greatest range in temperature, 129 F, was found at Elbert, in the southwest corner of Elbert County and about 40 miles south-southeast of Denver. The highest temperature recorded, 106 F, occurred on 7 August at Las Animas, in Bent County in the Plains area in southeastern Colorado. The lowest temperature, -38 F, was reported on 1 January from Taylor Park, which is located in the northeastern part of Gunnison County, about 10 miles west of the Continental Divide. In general, the winter temperatures east of the mountains are mainly a function of latitude, while in the mountains, they are more a function of altitude. By the five "divisions" or drainage basins, the maximum and minimum temperatures, and maximum and minimum temperature ranges for calendar year 1975 are given in Table 1.3.

Grand Junction is the only station within the AQCR or the AQMA which has its own Local Climatological Data (LCD) provided by the National Climatic Center (NCC). This LCD is a more comprehensive data presentation than the previously mentioned NWS data. Although Grand Junction data are not strictly comparable to those from Tract C-a, Grand Junction LCD summary constitutes the longest known climatological record available in this area. Tabulated data based on up to 85 years of records may be found in NCC publication 1975.

The following climatological summary for Grand Junction, Colorado, was adapted from the narrative summaries prepared by the NCC for 1975 and 1976.

TABLE 1.2

NATIONAL WEATHER SERVICE STATIONS WITHIN THE COLORADO-UTAH OIL SHALE INTERSTATE AQMA, AS OF 1975, RBOSP

County Name	No. of Stations	Location (see Figure 1.1)	Station Type[a]	Years of Record[b]		
Garfield	5	Altenbern	1,2,3	T: 17;	P: 28;	E: --
		Glenwood Springs, 1 mile north	1,2,3	62	68	--
		Grand Valley	1,2,3	11	11	--
		Rifle	1,2,3,C	55	60	--
		Shoshone	2	--	66	--
Mesa	10	Bonham Reservoir	2	--	13	--
		Collbran, 2 miles southwest	1,2,3	(data not given)		
		Colorado Natl Monument	1,2,3	29	34	--
		Fruita	1,2,3	69	75	--
		Gateway, 1 mile southwest	1,2,3	18	28	--
		Glade Park Store (closed May 75)	2	--	4	--
		Grand Junction Airport	1,2,3,C	83	84	--
		Grand Junction, 6 miles east-southeast	1,2,3,4	14	14	14
		Mesa Lakes Resort	1,2,3	5	5	--
		Palisade	1,2,3	52	62	--

[a]Station types are as follows:

"1" = average temperature and departure from normal
"2" = total precipitation and departure from normal
"3" = temperature extremes and freeze data
"4" = total evaporation and wind movement
"C" = recording rain gage station
"S" = storage precipitation station

[b]Years of Record are shown for temperature, precipitation, and evaporation. When a station was opened or closed during the year, the month of the action is shown. "Inactive" means that the station is closed indefinitely, but in some cases data were reported from it during the year.

TABLE 1.3

NATIONAL WEATHER SERVICE MAXIMUM AND MINIMUM TEMPERATURES IN COLORADO IN 1975, WITH LOCATIONS AND DATES, RBOSP

Division No.	Division Name	Max Temp, Location, Date	Min Temp, Location, Date	Max Range, Location, High and Low	Min Range, Location, High and Low
01	Arkansas River Drainage Basin	106 F Las Animas 8/7/75	-31 F Westcliffe 1/12/75	122 F Delhi 104, -18	94 F Ruxton Park 79, -15
02	Colorado River Drainage Basin	102 F Uravan 8/2/75	-38 F Taylor Park 1/1/75	127 F Steamboat Spr. 91, -36	90 F Mesa Verde N.P. 91, +1*
03	Kansas Drainage Basin	103 F Wray 1/9/75	-11 F Akron, Flagler 1/12/75	112 F Stratton, Akron 102, -10 101, -11	86 F Burlington 85, -1
04	Platte River Drainage Basin	103 F Julesburg 8/31/75	-37 F Antero Reservoir 2/19/75	129 F Elbert 93, -36	95 F Grant 84, -11
05	Rio Grande Drainage Basin	89 F Monte Vista 7/9/75	-35 F Center 1/3/75	120 F Center, Manassa 85, -35 87, -33	86 F Wolf Creek Pass 71, -15

*The station at Mesa Verde National Park was the only station in the State not to report a minimum temperature for 1975 that was below zero Fahrenheit.

Located in a large mountain valley, at the junction of the Colorado and Gunnison Rivers, on the western slope of the Rockies, Grand Junction has a climate marked by the wide seasonal range usual to interior localities at this latitude. Because of the protective topography of the vicinity sudden and severe weather changes are infrequent. Elevation of the valley floor ranges from 4,400 to 4,800 feet above MSL, with mountains on all sides at distances of from 10 to 60 miles, reaching heights of 9,000 to over 12,000 feet. This mountain valley location, with attendant "valley breezes," provides protection from spring and fall frosts resulting in a growing season averaging 191 days in Grand Junction. The upper valley around Palisade has about the same growing season, but it is three to four weeks shorter near the river west of Grand Junction, where the valley breeze is less effective. In general, areas located on mesas enjoy longer frost-free seasons than adjacent lower-lying ground where cool air tends to collect at night. This effect is more noticeable to the west, or lower, end of the valley. This phenomenon of cold air drainage, the effect of altitude, and frequent radiational cooling found in the very dry, clear climate of the western slope of the Rockies account for many of the very low minimum temperatures found in the western or mountainous part of the state as was shown in Table 1.3.

Relatively low precipitation occurs in the area because of the interior, continental location, ringed by mountains on all sides. As a consequence, agriculture is dependent on irrigation, for which an adequate supply of water has been available from mountain snowmelt and rain runoff. Summer rains occur chiefly as scattered light showers from clouds which form over nearby mountains. Winter snows are fairly frequent but mostly light and melt quickly. Even the infrequent snows of from four to eight inches, which are heavy for this locality, seldom remain on the ground for prolonged periods. Blizzard conditions in the valley are extremely rare.

Temperatures at Grand Junction have ranged from 105 F to -23 F, but readings of 100 F or higher are infrequent, and about one-third of the winters have no readings below 0 F. Summer days with maximum temperatures in the middle and low 90's and minimum temperatures in the low 60's are common. Relative humidity is very low in the summer, with values close to those of other dry locales such as the southern parts of New Mexico and Arizona. Spells of

cold winter weather are sometimes prolonged due to cold air becoming trapped in the valley. Winds are usually very light during the coldest weather. Changes in winter are generally gradual, and abrupt changes are much less frequent than in eastern Colorado. "Cold waves" are rare. Sunny days predominate in all seasons.

Visibilities of 20 miles or more and ceilings of 5,000 feet or higher prevail approximately 95 percent of the time. Gusty surface winds are frequent in spring and early summer. The prevailing wind is from the east-southeast due to the valley channeling effect, but the strongest winds are usually from the south and southwest and are associated with thunderstorms or with pre-frontal weather.

II. TRACT C-a

As illustrated in Figure 1.1, Tract C-a of the Rio Blanco Oil Shale Project (RBOSP) is located in the southwestern portion of Rio Blanco County, Colorado, near the headwaters of Yellow Creek, a northward-flowing tributary of the White River. The White River flows westward through Rio Blanco County and enters the State of Utah near its confluence with the Green River at the town of Ouray, Utah. This drainage is a portion of the Colorado River basin. Elevations in the near vicinity of Tract C-a range from 8,700 feet (2,655 m) for some of the higher points along Cathedral Bluffs to the west and southwest of the site, to below 6,200 feet (1,890 m) in some of the creek bottoms to the northeast. Distances from Tract C-a boundaries to these elevations are on the order of 8 to 10 km to the southwest, and 10 km to the northeast.

The main sampling site (60-m tower) is located at approximate Universal Transverse Mercator (UTM) grid coordinates 710 km east and 4,421 km north in UTM Grid Zone 12, and is at an elevation of about 7,380 feet (2,250 m) above Mean Sea Level (MSL). The terrain in the immediate vicinity of the main tower (also called "Site 1") slopes gently downward to the northeast, while farther away to the northeast, east, and southeast there are many deep ravines or gulches which cut the general level of the plateau 200 feet or more.

The area is sparsely populated. The nearest town is Rangely, Colorado, which is about 20 miles to the northwest (straight-line distance). Tract C-a is situated about 200 miles west of Denver and 185 miles east-southeast of Salt Lake City.

Although two years of meteorological data do not constitute a normal climatological data base, general summary observations can be made. These observations are described in this section.

The Tract C-a area is surrounded by high mountains. As a result, many migratory low pressure systems are deflected around the region. Stationary high-pressure cells often persist for several days, their passage blocked by the Continental Divide east of Tract C-a. As a result, there is a high frequency of clear sunny days with light winds and large diurnal temperature changes. Gradient winds are generally westerly, existing throughout the year, except when interrupted by the passage of frontal systems. Precipitation measurements indicate relatively low annual accumulations such as those of semi-arid steppe regions. In addition, the data indicate a high degree of temporal and spatial variability in tnis area, which is to be expected given the rough terrain with its variations in elevation and exposure. The infrequent occurrences of precipitation, fog, and small light-scattering airborne dust have produced excellent visibility, in general, for the Tract C-a area.

Local topography within the Tract C-a area has a much more pronounced effect on surface flows than the macroscale processes. Specific air movements produced by local conditions are often different from those expected from the major gradient flow. There is a tendency for wind velocities to be lowest at sunrise, when there is little vertical thermal mixing and the lower surface air does not couple with the more freely moving upper air. Conversely, velocities of local winds are greatest in the early afternoon hours when the air exhibits its greatest tendency to move vertically due to terrestrial heating, and couples with the faster air moving above it.

In the absence of strong gradient winds, the local terrain produces special meteorological conditions. During warm afternoon hours, the laterally constricted, but vertically expanding, air tends to flow up the valley. This air motion probably develops simultaneously with anabatic (upslope) winds which result from a greater heating of the valley side than the valley floor. At night, the reverse process occurs with the cold, dense air at higher elevations draining into the depressions. The greater radiative heat loss affecting the higher elevations (especially if they are snow covered) cools the air immediately adjacent to the surface, and this air sinks into the valley. Downward flowing cold air set in motion by this effect forms downslope winds leading to an accumulation of cold, dense, stable air in the valley bottom.

The high Cathedral Bluffs to the west of Tract C-a and the deep gulches to the east effectively channel surface winds, and thereby decouple the upper level flows from the surface flows much of the time (Nelson 1975). Several studies (CER Geonuclear 1971, Engineering Science, Inc. 1974, and Nelson 1975) have shown that airflow within the canyons of the Piceance Creek and Yellow Creek Basins is influenced by drainage winds in their respective channels, whereas winds measured atop the ridge-like portions of the basin closely follow the gradient wind regime. It can be inferred that these drainage winds occur in conjunction with stronger temperature inversions within the valley than at the ridge regions.

III. COMPARISON OF REGIONAL AND TRACT C-a DATA

General summaries of regional climatology and Tract C-a "climatological" trends are presented in Sections I and II of this chapter. A comparison of these discussions indicates a general degree of similarity.

The specific data are presented in Tables 1.4 and 1.5 for 1975 and 1976, respectively. The unavailability of the Climatological Data for Colorado, Annual Summary 1976 limits the number of comparisons that can be made using 1976 data.

TABLE 1.4

COMPARISON OF TEMPERATURE, PRECIPITATION, AND EVAPORATION DATA IN THE TRACT C-a VICINITY (50-MILE RADIUS) FOR 1975, RBOSP

Station	County	Air Temperatures (F)				Precip (in.)		Evap (in.)		Total Wind (miles)
		Min	Max	Mean	Dep[1/]	Amt	Dep[1/]	Amt	Dep[1/]	
Altenbern	Garfield	-17	95	44	--	14.66	--			
Collbran, 2 miles southwest	Mesa	-18	94	--	--	13.05	--			
Colorado Natl Mon	Mesa	-2	95	--	--	11.55	+0.56			
Dinosaur Natl Mon	Moffat	-11	96	46	--	13.69	--			
Fruita	Mesa	-18	98	49	-1.8	9.43	+1.13			
Grand Junction Arpt	Mesa	-8	99	50	-2.5	9.18	+0.77	38.36[2/]	-5.2[3/]	19,564[4/]
Grand Junction, 6 miles east-southeast	Mesa	-6	98	--	--	9.45	--			
Grand Valley	Garfield	-13	101	47	--	10.51	--			
Little Hills	Rio Blanco	-29	93	--	--	15.34	--			
Meeker No. 2	Rio Blano	-22	91	43	--	12.72	--			
Palisade	Mesa	-2	100	51	-3.6	9.11	0.00			
Rangely	Rio Blanco	-18	98	44	--	11.13	--			
Rifle	Garfield	-20	95	44	-2.9	9.24	-2.00			
RBOSP, Study Area [8/]	Rio Blanco	-28	92	41[6/]	--	5.97[7/]	--	27.56[5/]	--	--

1/ Departure from normal
2/ Total amount of evaporation for four months: May, June, July, and September 1975.
3/ Average monthly departure from normal, four-month period
4/ Total miles of wind for five months, April through July, September 1975
5/ Total evaporation, in inches, as measured at Site 3, RBOSP, for 4-1/2 months, 1 June through 18 October 1975.
6/ Average of all four sites
7/ Total for the year for the study site have the highest total amount (Site 4)
8/ Temperatures at 10-m level.

TABLE 1.5

COMPARISON OF TEMPERATURE, PRECIPITATION, AND EVAPORATION DATA FOR FIVE STATIONS IN THE TRACT C-a VICINITY FOR 1976, RBOSP

Station	County	Air Temperature (F)				Precip (in.)		Evap (in.)		Total Wind (miles)
		Min	Max	Mean	Dep[3/]	Amt	Dep[3/]	Amt	Dep[3/]	
Grand Junction Arpt	Mesa	-10	105	52	NA	5.27	NA	59.01[2/]	NA	12,895[2/]
Little Hills	Rio Blanco	-22	95	43	--	12.44	--			
Meeker No. 2	Rio Blanco	-21	95	44	--	11.70	--			
Rangely	Rio Blanco	-26	103	45[1/]	--	5.72[1/]	--			
RBOSP Study Site [4/]	Rio Blanco	-28	92	41[5/]	--	7.98[6/]	--	34.49[7/]	--	---

[1/] Data for the month of June were missing for this station.

[2/] Data for station 6 miles east-southeast of Grand Junction Post Office, total for six months.

[3/] Departure from normal

[4/] Temperature at 10-m level

[5/] Average of all four sites

[6/] Total for the year for the study site having highest total amount (Site 4).

[7/] Total evaporation, in inches, as measured at Site 3, RBOSP, for 30 April to 27 October 1976 (6 months).

The Tract C-a temperature data are representative of the region. The 1975 annual precipitation recorded for the study area was one-third lower than the lowest value reported from the other stations in the area, and less than half of that of the station with the highest reported annual precipitation. To further delineate distribution of precipitation on Tract C-a, additional precipitation measuring instruments of the weighing type were installed. The comparison between these precipitation instruments is presented in Chapter 2. The 1976 annual precipitation for Tract C-a is within the range of the other local stations presented (Table 1.5).

As indicated in Section I of this Chapter, visibility at the Grand Junction observation point exceeds 20 miles 95 percent of the time. Tract C-a data indicate that the visibility is greater than 20 miles for approximately 86 percent of the observations. This relatively good agreement indicates regional similarity of the Tract C-a visibility data.

The evaporation rates measured at Tract C-a are less than those reported at Grand Junction. The elevations of these stations are 6,540 feet (1,994 m) and 4,760 feet (1,451 m), respectively. The elevation may account for a portion of this difference.

Of the weather stations within about 50 miles of the RBOSP Tract C-a site in 1975, one station (Bonanza, Utah) could not be represented because no data were available; one station (Cliff Lakes) is only a storage precipitation station; and for the remaining 13, while all have some data, the type of data available varies. As can be seen in Tables 1.4 and 1.5, the climatological data variation within this 50-mile radius of Tract C-a is not as large as is that found within the entire State of Colorado. This is not surprising, given the much smaller area and the relatively lower relief than was found in the higher parts of the Rockies to the east and southeast of the site. In general, the agreement among the 13 stations and the RBOSP site itself is good, considering the variations in terrain and exposure.

A comparison of upper air to "regional" data has been made using the climatological data originated by Holzworth (1972). A brief abstract of the more pertinent data from his publication is presented in Table 1.6. Although these data were developed with urban air pollution in mind, the differences between adjacent stations may be considered as being indicative of the gradient of the observed parameter in each case. Thus, the interpolation made to derive an approximate value for the RBOSP Tract C-a area is qualified to that extent. The summary value based upon Tract C-a data is also presented. Strict comparisons between the values obtained in this manner and those measured or calculated as a result of the upper air program of 1974-1975 should probably not be attempted, due to wide variability among the data sets. Specific Upper Air Meteorological data are presented in Chapter 3.

TABLE 1.6

TABULATIONS OF MEAN SEASONAL AND ANNUAL MORNING AND AFTERNOON MIXING HEIGHTS (H) AND WIND SPEEDS (U) FOR SIX UPPER-AIR OBSERVING STATIONS IN THE WESTERN UNITED STATES[6], RBOSP

Station Location	Years of Data	Time[1]	Winter H[2]	Winter U[3]	Spring H[2]	Spring U[3]	Summer H[2]	Summer U[3]	Fall H[2]	Fall U[3]	Annual H[2]	Annual U[3]
Albuquerque, New Mexico	1960-1964	M	391	4.0	553	4.5	582	3.7	414	3.5	485	3.9
		A	1464	5.8	3452	8.9	3941	6.0	2295	5.5	2788	6.5
Denver, Colorado	1960-1964	M	219	4.8	423	4.6	255	3.7	174	3.6	268	4.2
		A	1482	6.3	3070	7.6	3458	6.1	2161	5.3	2543	6.3
Grand Junction, Colorado	1960-1964	M	329	3.4	628	5.4	307	4.7	273	3.9	384	4.3
		A	1160	3.4	3166	6.6	3940	6.1	2133	4.6	2600	5.2
Lander, Wyoming	1960-1964	M	223	2.8	511	3.7	337	2.7	322	2.9	348	3.0
		A	926	4.1	2755	6.9	3490	6.6	2030	5.0	2300	5.6
Salt Lake City, Utah	1960-1964	M	329	4.3	419	5.4	216	4.6	238	4.6	300	4.7
		A	944	4.6	2675	6.6	3737	6.2	1933	5.5	2322	5.7
Winslow, Arizona	1962-1964	M	223	3.0	270	4.2	232	3.3	213	2.6	234	3.3
		A	1128	5.6	3178	8.9	3840	7.1	2303	5.2	2613	6.7
Mean of Grand Junction and Lander (weighted)[7]		M	308	3.3	605	5.1	313	4.3	283	3.7	377	4.0
		A	1113	3.5	3084	6.7	3850	6.2	2112	4.7	2540	5.3
Mean of Tract C-a Upper Air Data		M	632	11.2[4]	935	6.7[4]	179	2.05[4]	158	4.8[4]	370	
		A	850		--		--		--		850[5]	

[1] M = morning, A = afternoon
[2] Mixing height in meters
[3] Wind speed in meters per second
[4] Combined afternoon and morning average
[5] Only winter data available
[6] Source: Holzworth, G.C., 1972: Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution throughout the Contiguous United States. Research Triangle Park, N.C., USEPA, Office of Air Programs.
[7] Weighted according to the approximate linear distance between Grand Junction, RBOSP, and Lander: i.e., {4 x (GJT) + 1 x (LND)}/5 = weighted mean value.

CHAPTER 2 - SURFACE METEOROLOGY

I. DATA ACCUMULATION PROCEDURES

The meteorological data acquisition system includes measurement and recording systems at Sites 1, 2, 3, and 4, (Figure 1.2). The main station was located at Site 1, which has a 60-m meteorological tower. Wind speed, wind direction, air temperature, wind direction variability (wind sigma), and relative humidity were measured at the 10-m level. Ambient air temperature, wind speed, and wind direction were also measured at the 30-m and 60-m levels. Temperature difference between the 10-m and 60-m levels was recorded. In addition, precipitation and insolation (solar radiation) were monitored at approximately 1.5 m above ground level at Site 1.

The following parameters were not part of the automatic data acquisition system, but were monitored routinely or seasonally:

- Evaporation rate at Site 3;
- Snow depth and water content at Site 1; and
- Visibility at Site 1.

At each of the remote sites (2, 3, and 4) there was a 10-m meteorological tower. Wind speed, wind direction, and ambient air temperature were measured at the 10-m level, and precipitation was measured at approximately the 1.5 m level, at all three of the remote sites.

Reliability of baseline meteorological data was assured by a comprehensive quality assurance program, established to meet the requirements specified in 10 CFR 50, Appendix D. Maintenance, operation, calibration, handling, shipping, storage, and inspection procedures were documented. Calibration procedures were traceable to established standards. Calibration schedules were established and rigorously executed. Quality assurance audits were

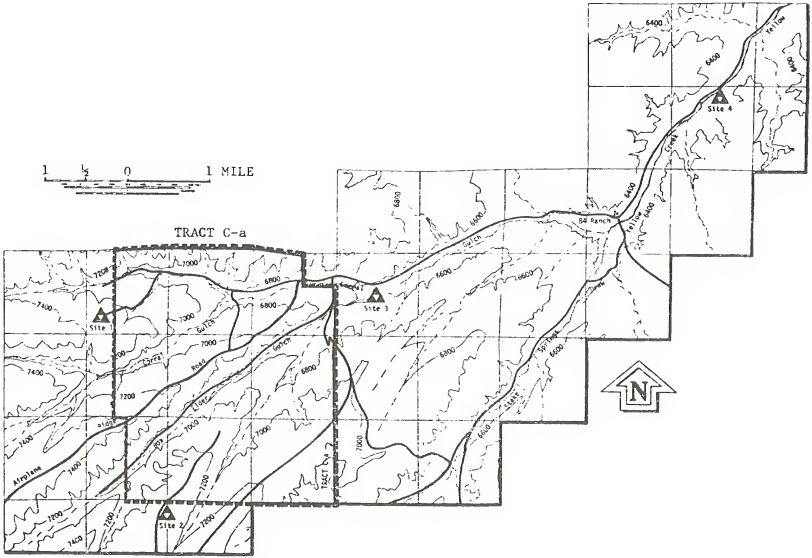

FIGURE I-2

TOPOGRAPHIC MAP OF AREA AROUND TRACT C-a SHOWING LOCATIONS OF METEOROLOGICAL AND AIR QUALITY STATIONS

scheduled and performed to monitor compliance with calibration and equipment maintenance procedures and other elements of the program. Discrepancies were documented and resolved. Any deviations were documented, and affected data verified, before being incorporated into the data base. The documentation system was program-wide and was continuously up-dated.

Percentage of data recovered for the monitored parameters was computed and updated throughout the baseline data collection. This has been done to show the effort being made to satisfy the Oil Shale Lease Environmental Stipulations.

The original stipulations state that ". . . the Lessee shall establish a meteorological station in reasonable proximity to each proposed plant site to monitor, at least 95 percent of each lease year during which monitoring is required . . ." The annual, cumulative data recovery percentages by type of parameter for both baseline years are presented in Table 1.7.

An Amendment of the Oil Shale Lease Serial Number C-20046, Tract C-a, was received by EG&G on December 8, 1976.

The amendment redefines air quality and meteorology data quality and quantities as follows:

> "In the design and operation of the baseline data collection and monitoring programs, the Lessee shall strive to collect data for the greatest period of time practicable with emphasis on acquisition of quality data. The Lessee shall establish and implement a quality assurance program approved by the Mining Supervisor to assure high quality data collection. This quality assurance program shall include but not be limited to: quality control by standard reference materials, such as those available through the National Bureau of Standards; data validation through established criteria of acceptability; method and frequency of calibration and maintenance; and testing programs to identify and quantify data anomalies."

TABLE 1.7

METEOROLOGY ANNUAL CUMULATIVE DATA RECOVERY PERCENTAGE,[1/]
(1 FEBRUARY 1975 THROUGH 31 JANUARY 1977) RBOSP

Parameter	Annual Percentage of Recovery[2/] 1975-1976	1976-1977
Visibility Measurements[3/]	100.0	100.0
Precipitation	99.8	98.0
Solar Radiation	92.6	97.4
Snow Course	100.0	100.0
Evaporation	100.0	100.0
Wind Speed (WS)	99.0	96.0
Wind Direction (WD)	99.1	97.4
Air Temperature (AT)	98.8	97.4
Relative Humidity (RH)	99.1	97.4
Temperature Difference (ΔT, 10-60 m)	98.6	97.2
Wind Sigma (σ)	98.4	95.5

[1/]If the total operational hours are used for the numerator of the "Monthly Percentage Recovered" equation, the percentage of data recovered would be larger.

[2/]Goal: $\geq$95%

[3/]Visibility data are discussed in Chapter 6.

The equation used to determine monthly data recovery percentages is given below.

$$\text{Monthly Percentage Recovered} = \frac{\text{Actual Recovered Data (hours)}}{\text{Total Possible Recovered Data (hours)}} \times 100\%$$

In this equation:

Actual Recovered Data include:

- Data collected, processed, analyzed, and reported under quality assurance control;
- Data temporally bracketed by routine calibration data;

Total Possible Recovered Data hours are total hours in a month minus:

- Calibration periods: Although recorded data are not available for analysis or use, as part of the baseline data, the recovery rates are not penalized for critical calibration time.
- Force Majeure periods; Although data are not always reliably recorded during these periods, time of force majeure is not included as part of total possible recovered data. Force majeure is defined as those conditions that are not practically controllable or avoidable such as storms, lightning, snow, extreme winds, public power failures, or severe acts of God.
- Maintenance periods: Although data are not always reliably recorded during these periods data from detection of the discrepancy to remedy are deleted from total possible hours.

On a monthly basis, the "Monthly Percentage Recovered" was determined for each air quality and meteorological parameter and location combination using this equation.

From "Monthly Percentage Recovered" values a "Percentage Recovered Through the Month" has been calculated using the following equation:

$$\text{Percentage Recovered Through the Month} = \left[\frac{\left(\begin{matrix}\text{\% present}\\ \text{month*}\end{matrix}\right)\left(\begin{matrix}\text{total days}\\ \text{present}\\ \text{month}\end{matrix}\right) + \left(\begin{matrix}\text{\% through}\\ \text{previous}\\ \text{month}\end{matrix}\right)\left(\begin{matrix}\text{total days}\\ \text{through}\\ \text{previous}\\ \text{month}\end{matrix}\right)}{\text{Total Days Through Present Month}}\right] \times \left[100\%\right]$$

*from equation for Monthly Percentage Recovered

The cumulative percentage by type of parameter, for those sites and locations where the parameter is measured, is calculated by the following equation using the "Percentage Through the Month" values:

$$\text{Percentage Recovered By Type of Parameter} = \frac{\sum_{1}^{n^*} \text{Percentage Through the Month for Location } n^*}{n^*}$$

*n = numerical count of locations at which parameter is measured

These annual meteorological percentages, in combination with the stringent quality assurance program, satisfy the quality and quantity requirements of the Oil Shale Lease Environmental Stipulations.

The meteorological parameters that are measured at RBOSP, Tract C-a have been indicated as lease requirements by the Area Oil Shale Office (AOSO). The selection of these parameters was a joint effort of the AOSO, regulatory agencies, and the lessee.

Meteorological parameters are measured to define the airflow characteristics and near-surface atmospheric stability throughout the project area on a continuous basis. In addition, these data are collected for use as input information for: engineering evaluation and design and other environmental evaluations, such as air quality, aquatic and terrestrial ecology, etc.

Atmospheric stability is used here to describe the ability of the atmosphere to suppress (stable) or enhance (unstable) turbulent air which tends to disperse effluents. The data taken are representative for the period of record and can be used with long-term records from nearby weather stations to extend the period of validity and/or representativeness. This information is used to describe existing atmospheric conditions and to provide the primary numerical input to atmospheric diffusion models which are used to predict the air quality impact of the various project emissions.

II. SITE DATA

A. Annual Summaries

Annual summaries for continuously measured meteorological parameters are presented for 1975-1976 and 1976-1977, respectively, in Tables 1.8 and 1.9 The minimum and maximum values are individual "hourly" data points. The "hourly" values recorded on-site are a representative 15-minute average of each hour taken during the last quarter of each hour. The mean values presented in the table for 1975-1976 were obtained by averaging all the individual hourly values. The mean values for 1976-1977 were obtained by a time-weighted averaging computation of seasonal values previously reported, which provided comparable values with 1975-1976 data.

The data presented in these tables show excellent agreement for the two-year period. From this and previous reports it can be inferred that any variation between these parameters for the two years was not temporally significant.

Meteorological parameters measured for RBOSP that are not presented in Tables 1.8 and 1.9 are presented separately in a different format. These parameter dependent formats have been chosen to provide a clearer understanding of each parameter characteristic.

TABLE 1.8

SUMMARY OF ANNUAL (FEBRUARY 1975 THROUGH JANUARY 1976)
MINIMUM, MAXIMUM, MEAN VALUES OF METEOROLOGICAL PARAMETERS
MEASURED ON TRACT C-a, RBOSP

Parameter	Units	Minimum[1/]	Maximum[1/]	Mean
	SITE 1			
Wind Speed (10 m)	mph	0.56	30.82	7.72
Wind Speed (30 m)	mph	0.56	39.12	9.04
Wind Speed (60 m)	mph	0.53	43.04	10.59
Wind Direction Sigma (10 m)	Degrees	0.01	59.26	11.77
Air Temperature (10 m)	C	-21.10	30.07	6.08
Air Temperature (30 m)	C	-22.10	27.00	5.56
Temperature Difference (10 to 60 m)	C	-4.69	6.22	0.11
Relative Humidity (10 m)	%	10.00	93.12	35.99
	SITE 2			
Wind Speed (10 m)	mph	0.01	36.70	9.08
Air Temperature (10 m)	C	-21.44	27.47	5.52
	SITE 3			
Wind Speed (10 m)	mph	0.06	29.90	6.61
Air Temperature (10 m)	C	-28.20	28.97	4.33
	SITE 4			
Wind Speed (10 m)	mph	0.00	31.23	5.92
Air Temperature (10 m)	C	-33.30	33.14	4.39

[1/] Hourly values for this period.

TABLE 1.9

SUMMARY OF ANNUAL (FEBRUARY 1976 THROUGH JANUARY 1977)
MINIMUM, MAXIMUM, MEAN VALUES OF METEOROLOGICAL PARAMETERS
MEASURED ON TRACT C-a, RBOSP

Parameter	Units	Minimum[1/]	Maximum[1/]	Mean
	SITE 1			
Wind Speed (10 m)	mph	0.61	32.31	7.18
Wind Speed (30 m)	mph	0.60	36.25	8.66
Wind Speed (60 m)	mph	0.56	56.61	10.04
Wind Direction Sigma (10 m)	Degrees	0.39	34.52	11.88
Air Temperature (10 m)	C	-21.70	29.73	7.22
Air Temperature (30 m)	C	-21.30	29.06	7.14
Temperature Difference (10 to 60 m)	C	-4.79	7.43	0.08
Relative Humidity (10 m)	%	12.13	92.43	30.60
	SITE 2			
Wind Speed (10 m)	mph	0.59	39.20	8.40
Air Temperature (10 m)	C	-22.20	29.40	6.91
	SITE 3			
Wind Speed (10 m)	mph	0.51	26.42	6.92
Air Temperature (10 m)	C	-25.30	32.11	5.74
	SITE 4			
Wind Speed (10 m)	mph	0.54	28.39	5.71
Air Temperature (10 m)	C	-31.50	33.36	5.01

[1/] Hourly values for this period.

Wind direction/speed summaries for 1975-1976 and 1976-1977 are presented in Figures 1.3 and 1.4, respectively, for all sites at the 10-m level. These figures indicate strong similarities between the two years. Two exceptions are a more predominant west-northwest annual component for the second year than the first at Site 3, and a less predominant south-southwest component for the second year than the first at Site 4.

Annual precipitation summaries (Tables 1.10 and 1.11) indicate that Tract C-a baseline values for 1975-1976 were considerably lower than in 1976-1977. Values were low for both years. However, the 1975-1976 annual precipitation values were unexpectedly low. To further verify the type of measurement made by the tipping bucket type of precipitation instruments, weighing type instruments with "Alter" shields, were installed. Two weighing instruments were installed, one at Site 1 and one at Site 2; both were installed within 25 feet of the existing tipping bucket instruments.

After the first quarter of "weighing" precipitation data were available, a special analysis was performed using the data for July and August 1976. The analysis indicated that the comparison was most meaningful if performed on a precipitation occurrence by occurrence basis. This analysis indicated that of the 30 available occurrences only four did not fall within the manufacturer's specified accuracy range. In comparing the monthly values presented in this report for the same instrument accuracy requirements, the tipping bucket type appears to record data values an average of 18 percent lower than the weighing gage (Table 1.12). This slight discrepancy does not account for the unexpected low values measured during 1975-1976.

Variations in local terrain which contribute to highly localized thunder-showers may be the primary cause for differences in measured precipitation values in the area, since instrument malfunctions do not appear to be responsible.

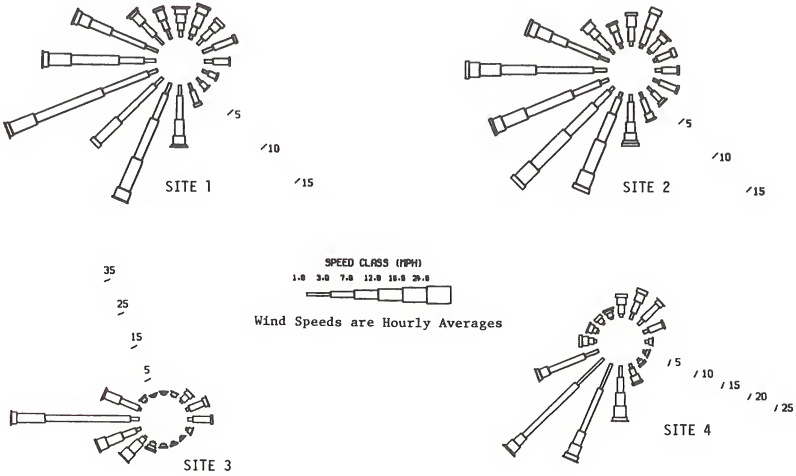

FIGURE 1.3

ANNUAL (FEBRUARY 1975 THROUGH JANUARY 1976) WIND ROSES FOR THE 10-M LEVEL FOR SITES 1, 2, 3, AND 4, RBOSP.

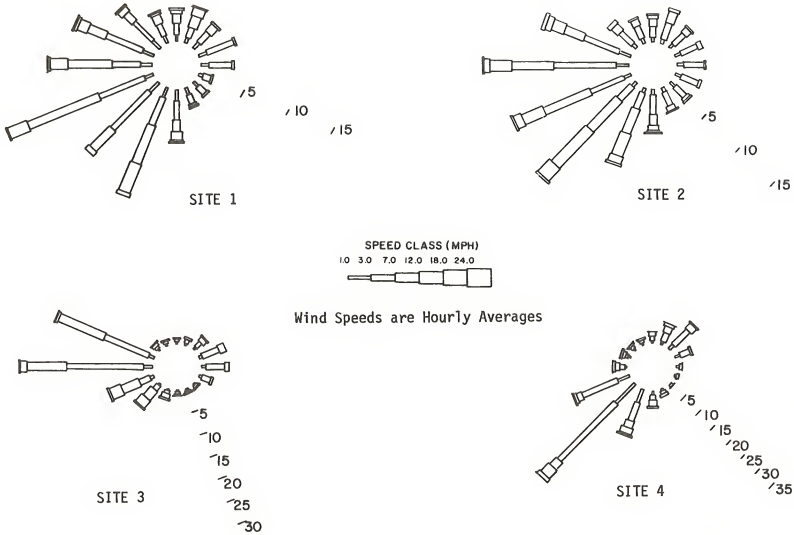

FIGURE I.4

ANNUAL (FEBRUARY 1976 THROUGH JANUARY 1977) WIND ROSES FOR THE 10-M LEVEL FOR SITES 1, 2, 3, AND 4, RBOSP

TABLE 1.10

SUMMARY FOR PRECIPITATION FROM TIPPING BUCKET GAGE (FEBRUARY 1975 THROUGH JANUARY 1976) RBOSP

Period	Precipitation (in.) Site 1	Site 2	Site 3	Site 4	Average[1/]
February 1975	0.01	0.04	0.05	0.32	0.11
March 1975	0.12	0.01	0.15	0.92	0.30
April 1975	0.14	0.07	0.28	0.57	0.27
May 1975	0.13	0.12	0.68	1.09	0.51
June 1975	0.05	0.03	0.12	0.44	0.16
July 1975	0.04	0.03	0.08	0.56	0.18
August 1975	0.02	0.00	0.13	0.04	0.05
September 1975	0.01	0.18	0.13	0.13	0.11
October 1975	0.06	0.24	0.49	1.17	0.49
November 1975	0.05	0.01	0.41	0.46	0.23
December 1975	0.01	0.01	0.41	0.21	0.16
January 1976	0.01	0.00	0.06	0.06	0.03
Seasonal					
Winter (February)	0.01	0.04	0.05	0.32	0.11
Spring (March, April, May)	0.39	0.20	1.11	2.58	1.07
Summer (June, July, August)	0.11	0.06	0.33	1.04	0.39
Fall (September, October, November)	0.12	0.43	0.93	1.76	0.81
Winter (December, January)	0.02	0.01	0.47	0.27	0.19
Annual (February 1975 through January 1976)	0.65	0.74	2.89	5.97	2.56

1/ Average is based upon sites with complete data only.

TABLE 1.11

SUMMARY FOR PRECIPITATION FROM TIPPING BUCKET GAGE (FEBRUARY 1976 THROUGH JANUARY 1977) RBOSP

Period	Precipitation (in.) Site 1	Site 2	Site 3	Site 4	Average[1/]
February 1976	0.57	0.02	0.46	0.67	0.43
March 1976	0.44	0.09	0.63	0.75	0.48
April 1976	0.50	0.42	0.30	0.87	0.52
May 1976	0.93	1.41	1.40	1.14	1.22
June 1976	1.48	1.54	1.08	1.41	1.38
July 1976	0.80	1.02	0.83	0.87	0.88
August 1976	0.51	0.98	0.61	1.31	0.85
September 1976	0.29[2/]	NA	0.73	0.59	0.66
October 1976	0.22	0.01[2/]	0.26	0.24	0.24
November 1976	0.00	0.02	0.00	0.02	0.02
December 1976	0.01	0.10	0.06	0.01	0.05
January 1977	0.05	0.36	0.39	0.10	0.23
Seasonal					
Winter (February)	0.57	0.02	0.46	0.67	0.43
Spring (March, April, May)	1.87	1.92	2.33	2.76	2.22
Summer (June, July, August)	2.79	3.54	2.52	3.61	3.12
Fall (September, October November)	0.51[2/]	0.03[2/]	0.99	0.83	0.91
Winter (December, January)	0.06	0.46	0.45	0.11	0.27
Annual (February 1976 through January 1977)	5.80[2/]	5.97[2/]	6.75	7.98	7.37[3/]

1/ Average is based upon sites with complete data only.

2/ Partial data only

3/ Average of annual site averages using site with complete data only.

NA - Data not available.

TABLE 1.12

SUMMARY FOR PRECIPITATION FROM WEIGHING GAGE
(JULY 1976 THROUGH JANUARY 1977), RBOSP[1/]

Period	Precipitation (in.) Site 1	Site 2
July 1976	0.98	1.13
August 1976	0.72	0.99
September 1976	0.76	0.69
October 1976	0.34[2/]	0.03[2/]
November 1976	0.00	0.00
December 1976	0.16	0.12
January 1977	0.55	0.45
Seasonal		
Summer 1976 (July and August)	1.70	2.12
Fall 1976 (September, October, November)	1.10[2/]	0.72[2/]
Winter 1976-1977 (December, January)	0.71	0.57
Annual (July 1976 through January 1977)	3.51[2/]	3.41[2/]

[1/] The two weighing rain gages were installed at the end of June 1976.

[2/] Partial data.

Solar radiation seasonal values follow the same general, annual trend. Although the maximum, seasonal, mean values occurred in Spring for 1975-1976, and in Summer for 1976-1977 and 1975-1976 mean values are in general higher than those in 1976-1977, no significant interpretation of these variations can be made, Tables 1.13 and 1.14.

Evaporation data in the annual summaries, Tables 1.15 and 1.16, do not indicate any trend except June, July, and August for both baseline years show higher evaporation rates than other sample months. The "evaporation season" mean values are comparable for both years.

Snow course measurements for 1975-1976 and 1976-1977 are presented in Tables 1.17 and 1.18, respectively. Snow course measurements for 1975-1976 were started with the first day of the baseline program and were terminated when the course was consistently clear of snow. For 1976-1977 the measurement started as soon as practical after the occurrence of the first measurable snowfall and ended with the termination of the two-year baseline study. Measurable snowfall accumulation for the second year was considerably later, 11 weeks, than that of the previous year.

B. Two-Year Summaries

Two-year summaries for climatology, meteorology, and air quality purposes provide little additional information over the annual summaries. This is particuarly true for a discrete parameter such as precipitation, which can vary widely within a given year, day, or hour at a site.

These summaries have been included to assist in the evaluation of interactions with other ecological investigations and engineering design efforts (Tables 1.19 through 1.22).

TABLE 1.13

MINIMUM, MAXIMUM, AND MEAN SUMMARY FOR SOLAR RADIATION AT SITE 1 (FEBRUARY 1975 THROUGH JANUARY 1976), RBOSP

Period	Insolation (Langleys)		
	Minimum	Maximum	Mean
February 1975	0.04	1.15	0.27
March 1975	0.10	1.47	0.40
April 1975	0.07	1.60	0.51
May 1975	0.22	1.73	0.61
June 1975	0.00	1.90	0.45
July 1975	0.00	1.70	0.39
August 1975	0.00	1.62	0.42
September 1975	0.00	1.34	0.35
October 1975	0.00	1.17	0.28
November 1975	0.00	0.93	0.18
December 1975	0.00	0.87	0.14
January 1976	0.00	0.84	0.16
Seasonal			
Winter (February)	0.04	1.15	0.27
Spring (March, April, May)	0.07	1.73	0.50
Summer (June, July, August)	0.00	1.90	0.42
Fall (September, October, November)	0.00	1.34	0.27
Winter (December, January)	0.00	0.87	0.15
Annual (February 1975 through January 1976	0.00	1.90	0.34

TABLE 1.14

MINIMUM, MAXIMUM, AND MEAN SUMMARY FOR SOLAR RADIATION AT SITE 1 (FEBRUARY 1976 THROUGH JANUARY 1977), RBOSP

Period	Insolation (Langleys)		
	Minimum	Maximum	Mean
February 1976	0.00	1.03	0.21
March 1976	0.00	1.37	0.29
April 1976	0.00	1.52	0.36
May 1976	0.00	1.63	0.39
June 1976	0.00	1.63	0.48
July 1976	0.00	1.57	0.43
August 1976	0.00	1.52	0.40
September 1976	0.00	1.38	0.32
October 1976	0.00	1.17	0.26
November 1976	0.00	0.89	0.19
December 1976	0.00	0.91	0.14
January 1977	0.00	0.94	0.15
Seasonal			
Winter (February)	0.00	1.03	0.21
Spring (March, April, May)	0.00	1.63	0.35
Summer (June, July, August)	0.00	1.63	0.44
Fall (September, October, November)	0.00	1.38	0.26
Winter (December, January)	0.00	0.94	0.15
Annual (February 1976 through January 1977)	0.00	1.63	0.31

TABLE 1.15

EVAPORATION DATA SUMMARY FOR 1975, SITE 3, RBOSP

End Date of Measurement Period	Time of Measurement (hr, MST)	Average Evaporation Rate ($g/cm^2/hr$) Observation Month
7 June 1975	0830	0.023
14 June 1975	1100	0.034 1/
21 June 1975	2/	2/
28 June 1975	1215	0.032
5 July 1975	1015	0.031
12 July 1975	1338	0.014
19 July 1975	0948	0.011
26 July 1975	1730	0.026
2 August 1975	1200	0.015
10 August 1975	1800	0.033
16 August 1975	1700	0.013
23 August 1975	1800	0.026
30 August 1975	0900	0.033
7 September 1975	0935	0.024
13 September 1975	1315	0.022
20 September 1975	1437	0.016
27 September 1975	1810	0.018
4 October 1975	1219	0.021
11 October 1975	1300	0.021
18 October 1975	1132	0.013 3/
Average Evaporation for the year 1975		0.022

1/ Temperature reading invalid. Thermometer not entirely submerged.

2/ Domestic stock broached enclosure for evaporation pan. Pan relocated inside Site 3 security fence.

3/ Evaporation measurements discontinued with this measurement for 1975 due to observed icing during the next sampling period.

TABLE 1.16

EVAPORATION DATA SUMMARY FOR 1976, SITE 3, RBOSP

End Date of Measurement Period	Time of Measurement (hr, MST)	Average Evaporation Rate ($g/cm^2/hr$) Observation Month
30 April 1976	1400	0.014
7 May 1976	0945	0.017
14 May 1976	1500	0.015
21 May 1976	1745	0.020
29 May 1976	1520	0.015
4 June 1976	1230	0.023
11 June 1976	1450	0.031
18 June 1976	1410	0.014
25 June 1976	1800	0.029
2 July 1976	1746	0.030
9 July 1976	1300	0.023
16 July 1976	1630	0.026
24 July 1976	2000	0.027
30 July 1976	1200	0.015
6 August 1976	1815	0.023
14 August 1976	0930	0.020
21 August 1976	1100	0.027
28 August 1976	1200	0.018
4 September 1976	1025	0.025
11 September 1976	1320	0.018
18 September 1976	0900	0.012
25 September 1976	1505	0.000
2 October 1976	1223	0.011
9 October 1976	1400	0.001
16 October 1976	1132	0.013
23 October 1976	1305	0.011
27 October 1976	1100	0.009 1/
Average Evaporation for the year 1976		0.018

1/ Last sample of the season.

TABLE 1.17

SUMMARY OF SNOW COURSE MEASUREMENTS AT SITE 1 (FEBRUARY 1975 THROUGH JANUARY 1976), RBOSP

Date of Sample	Total Snow Depth (In.)	Sample (In. of H_2O)
1 February 1975	7.5	0.15
5 February 1975	4.5	0.10
12 February 1975	5.5	0.20
16 February 1975	5.0	0.20
23 February 1975	3.5	0.10
11 March 1975	3.5	0.15
12 March 1975	2.0	0.10
17 March 1975	1.5	0.05
28 March 1975	1/	1/
1 April 1975	7.4	0.20
9 April 1975	1/	1/
23 October 1975	6.0	0.15
9 November 1975	1.5	0.01
27 November 1975	2.5	0.02
30 November 1975	3.0	0.10
15 December 1975	4.0	0.02
24 December 1975	2.0	0.01
31 December 1975	6.0	0.10
8 January 1976	4.2	0.11
16 January 1976	4.2	0.10
26 January 1976	4.5	0.10
Highest single value:	7.5	Average value: 0.10

1/ Several inches but drifted within the standard course measurement not taken.

TABLE 1.18

SUMMARY OF SNOW COURSE MEASUREMENTS AT SITE 1 (FEBRUARY 1976 THROUGH JANUARY 1977), RBOSP

Date of Sample	Total Snow Depth (In.)	Sample (In. of H_2O)
1 February 1976	3.8	0.10
7 February 1976	5.8	0.12
15 February 1976	2.0	0.10
16 February 1976	2.5	0.10
22 February 1976	7.0	0.12
28 February 1976	NA 1/	NA 1/
3 March 1976	6.5	0.13
5 March 1976	8.0	0.14
26 March 1976	3.0	0.10
6 November 1976	0.0	0.00
13 November 1976	0.0	0.00
20 November 1976	0.0	0.00
27 November 1976	0.0	0.00
4 December 1976	0.0	0.00
11 December 1976	0.0	0.00
18 December 1976	0.0	0.00
25 December 1976	0.0	0.00
1 January 1977	0.0	0.00
8 January 1977	2.5	0.10
15 January 1977	2.0	0.05
22 January 1977	0.0	0.00
24 January 1977	2.0	0.05
29 January 1977	1.0	0.03
Highest single value:	8.0	Average value: 0.10 2/

1/ NA - Data not available

2/ Only non-zero values were used in computing the average water content.

TABLE 1.19

SUMMARY OF BIENNIAL (FEBRUARY 1975 THROUGH JANUARY 1977)
MINIMUM, MAXIMUM, MEAN VALUES OF METEOROLOGICAL PARAMETERS
MEASURED ON TRACT C-a, RBOSP

Parameter	Units	Minimum[1/]	Maximum[1/]	Mean
	SITE 1			
Wind Speed (10 m)	mph	0.56	32.31	7.45
Wind Speed (30 m)	mph	0.56	39.12	8.85
Wind Speed (60 m)	mph	0.53	56.61	10.32
Wind Direction Sigma (10 m)	Degrees	0.01	59.26	11.83
Air Temperature (10 m)	C	-21.70	30.07	6.65
Air Temperature (30 m)	C	-22.10	29.06	6.35
Temperature Difference (10 - 60 m)	C	-4.79	7.43	0.10
Relative Humidity (10 m)	%	10.00	93.12	33.30
	SITE 2			
Wind Speed (10 m)	mph	0.10	39.20	8.74
Air Temperature (10 m)	C	-22.20	29.40	6.22
	SITE 3			
Wind Speed (10 m)	mph	0.06	29.90	6.77
Air Temperature (10 m)	C	-28.20	32.11	5.04
	SITE 4			
Wind Speed (10 m)	mph	0.00	31.23	5.82
Air Temperature (10 m)	C	-33.30	33.36	4.70

[1/] Hourly values for this period.

TABLE 1.20

COMBINED BIENNIAL (FEBRUARY 1975 THROUGH JANUARY 1977) SUMMARY FOR PRECIPITATION FROM THE TIPPING BUCKET GAGE, RBOSP

Period	Precipitation (in.)[2/]			
	Site 1	Site 2	Site 3	Site 4
February	0.58	0.06	0.51	0.99
March	0.56	0.10	0.78	1.67
April	0.64	0.49	0.58	1.44
May	1.06	1.53	2.08	2.23
June	1.53	1.57	1.20	1.85
July	0.84	1.05	0.91	1.43
August	0.53	0.98	0.74	1.35
September	0.30[1/]	0.18[1/]	0.76	0.72
October	0.28	0.25[1/]	0.75	1.41
November	0.05	0.03	0.41	0.48
December	0.02	0.11	0.47	0.22
January	0.06	0.36	0.45	0.16
Seasonal				
Winter (February)	0.58	0.06	0.51	0.99
Spring (March, April, May)	2.26	2.12	3.44	5.34
Summer (June, July, August)	2.90	3.60	2.85	4.65
Fall (September, October, November)	0.63[1/]	0.46[1/]	1.92	2.59
Winter (December, January)	0.08	0.47	0.92	0.38
Biennal Totals (February 1975-January 1977)	6.45[1/]	6.71[1/]	9.64	13.95

[1/] Partial data only.

[2/] Yearly averages for this two-year period may be obtained by dividing the above figures by 2.

TABLE 1.21

MINIMUM, MAXIMUM, AND MEAN BIENNIAL (FEBRUARY 1975 THROUGH JANUARY 1977) SUMMARY FOR SOLAR RADIATION AT SITE 1, RBOSP

Period	Insolation (Langleys) Minimum	Maximum	Mean
February 1975	0.00	1.15	0.24
March 1975	0.00	1.47	0.35
April 1975	0.00	1.60	0.44
May 1975	0.00	1.73	0.50
June 1975	0.00	1.90	0.47
July 1975	0.00	1.70	0.41
August 1975	0.00	1.62	0.41
September 1975	0.00	1.38	0.34
October 1975	0.00	1.17	0.27
November 1975	0.00	0.93	0.19
December 1975	0.00	0.91	0.14
January 1976	0.00	0.94	0.16
Seasonal			
Winter (February)	0.00	1.15	0.24
Spring (March, April, May)	0.00	1.73	0.43
Summer (June, July, August)	0.00	1.90	0.43
Fall (September, October, November)	0.00	1.38	0.27
Winter (December, January)	0.00	0.94	0.15
Biennial (February 1975 through January 1977)	0.00	1.90	0.33

TABLE 1.22

BIENNIAL (FEBRUARY 1975 THROUGH JANUARY 1977) SUMMARY OF EVAPORATION DATA, SITE 3, RBOSP

Year	N	Total Net Evaporation (in.)	Average Rate of Evaporation ($g/cm^2/hr$)
1975	19	27.56	0.022
1976	27	34.49	0.018
2-yr totals/ averages		62.05	0.020[1/]

[1/] The biennial average was formed by weighing the two annual averages by N, the number of observations in each year, then taking the average of the results.

C. Site to Site Variations

Meteorological parameters measured at all four sites (wind speed and direction 10-m, air temperature 10-m, and precipitation measurements) are strongly dependent upon the local terrain. This local terrain effect has been extensively discussed previously in this report and in other reports for the baseline period. In addition, site-to-site variations and similarities have been previously well documented.

In brief, the data from the valley sites (3 and 4) show strong similarities. The primary variations between the valley sites are that colder air accumulates at Site 4 and predominant wind directions are different due to the respective valley orientations. The data from the ridge sites (1 and 2) indicate two primary variations, which are lower wind speeds at Site 1 and altered predominant wind direction. This well-documented variation is due to the close proximity of a high knoll to the Site 1 tower.

Valley site as compared to ridge site variations are briefly summarized in the following. High wind speeds at the valley sites are generally associated with high winds at the ridge sites. However, high winds at the ridge sites are not necessarily associated with high winds within the valleys. The predominant southwest quadrant wind directions for the ridge sites, with 10-m Site 1 to Site 2 elevation variation excluded are representative of the regional air flow. The valley sites' predominant wind direction are due to the orientation of the valleys. The air temperature variations between valley and ridge sites are summarized as greater diurnal variations and colder temperatures at the valley sites. A prime factor in the site-to-site variations mentioned, except where noted otherwise, is the well documented drainage winds.

Precipitation site-to-site variations indicate a higher annual amount at valley sites than at ridge sites. Greater exposure at the ridge sites may contribute to this difference.

III. RELATIONSHIPS BETWEEN VARIOUS METEOROLOGICAL PARAMETERS

The inter-parametric relationships for RBOSP Tract C-a have been comprehensively presented in previous reports. A brief summary of these relationships is presented here. Further details may be obtained by review of the previous reports (RBOSP DDP, 1976). Similar calculations were performed for selected relationships using second-year data. These analyses indicated close agreement between the two years of data.

There is a tendency for wind velocities to be lowest about dawn, at which time there is little vertical thermal mixing, and the lower surface air does not couple with the more freely moving upper air. Conversely, velocities of local winds are greatest during the afternoon when the air near the surface exhibits its greatest tendency to move vertically due to terrestrial heating and couples with the faster air moving above it.

Inasmuch as wind sigma, delta temperature, and insolation are related to atmospheric stability, comparisons between the variables within stability categories were investigated. There is a lack of good comparison between delta temperature and wind sigma in relation to the defined stability classes. This discrepancy lies not with the data but with the classification scheme which was not designed for use in an area with as much topographical influence as found in the Tract C-a area. Because there is a lower frequency of occurrence of stable conditions defined from wind sigma measurements than from the delta temperature measurements, the latter method provides more conservative estimates of effluent dispersion. Delta temperature is much more dependent upon insolation than is wind sigma. This is due to the direct dependence of surface temperature on insolation. The average behavior of wind sigma and solar insolation shows a general increase in insolation with an increase in wind sigma.

Comparison of delta temperature with wind speed shows a general trend of higher wind speeds being associated with more unstable conditions. This agrees with the data presented in Chapter 5. The comparison of delta temperature with wind direction indicates a relative minimum in delta temperature (stable conditions) being associated with westerly winds (around 270 degrees). Comparison of wind speed with wind direction indicates a relative maximum in wind speed from the westerly direction. Comparison between wind sigma and wind speed shows little interrelationship. Higher wind speeds are associated with a high degree of mechanically induced turbulence. However, lower wind speeds cause the wind vane used for the measurement to meander more; this produces relatively high measurements of sigma. The net result is no relationship between sigma and wind speed. Comparison of wind sigma and wind direction indicates a relative minimum of wind sigma (stable conditions) for the westerly winds (around 270 degrees) which corroborates the similar conclusion using the correlation of delta temperature with wind direction.

Comparisons of relative humidity and wind speed, wind direction, delta temperature, and wind sigma have been made. There is an indication of decrease in relative humidity with increasing wind speed for wind speeds up to about 10 mph. For wind speeds above 10 mph, there is no apparent dependence of relative humidity on wind speed. The few points related to high relative humidity and high wind speed were associated with thunderstorm activity in the area. On the average, higher relative humidity was associated with northerly winds. In addition, relative humidity was greatest when the atmosphere was nearly isothermal (delta temperature near zero), but dropped markedly as the delta temperature increased or decreased. The relationship between relative humidity and wind sigma shows high values of relative humidity associated with high values of wind sigma; this may be due to the relationship of high relative humidity with northerly winds, with artificial values introduced into the wind sigma measurement by the 0 - 360 degree transition point of the wind direction sensors.

The comparison between annual precipitation and mean wind speed at a given site shows a decreased amount of precipitation with the increased mean wind speed. This relationship appears to be true for both types of precipitation gages that were used, although a sounder conclusion would have required weighing type gage data base for Site 3 and/or 4, and/or data obtained with a larger "wind shield" at Site 1 and/or Site 2.

The dispersion of pollutants is influenced by the presence of an atmospheric inversion. Inversions tend to trap airborne substances under a lid of air. In the baseline data years, inversion conditions existed 36.6 percent of the total hours of the year. A correlation for the relationship between inversion peristance and wind direction was determined. The results are shown in Table 1.23. Examination of the data shows that while over one third of the hours in the year have inversion conditions, the great majority are short-lived (one hour) and occur under all wind directions, the longer periods of inversion persistance occur during times when the wind was blowing from a single quadrant centered on the WSW direction. No inversion condition persisted for more than 10 hours. Inversion conditions were determined from delta-T measurements taken at Site 1.

TABLE 1.23

INVERSION PERSISTENCE AS OCCURRENCES

DUR	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NN	NNW	N
1	37	51	77	57	41	60	71	125	205	259	248	237	224	158	99	67
2	5	3	7			1	4	18	31	48	74	38	44	20	5	8
3	1			0				0	8	15	35	13	17	7	1	
4		0	0	0	0	0	0	3	5	2	14	7	5	2		0
5	0	0	0	0	0	0	0		2		7	2	1	0		0
6	0	0	0	0	0	0	0	0	0	0	2	1		1	0	0
7	0	0	0	0	0	0	0	0	0	0	2		0	1	0	0
8	0	0	0	0	0	0	0	0	0	0	1	0	0		0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CHAPTER 3 - UPPER AIR METEOROLOGY

The upper air studies program was performed for the Tract C-a Rio Blanco Oil Shale Project over four intensive 15-day quarterly periods during 1974 and 1975 as follows: Fall study, October 1 to 15, 1974; Winter study, January 20 to February 9, 1975; Spring study, April 14 to May 1, 1975; and Summer study, July 12 to 26, 1975. The measured data consisted of ambient temperature soundings from about 6,300 to 13,000 feet above MSL with values recorded at 100-foot increments, and wind speed and direction soundings from about 7,000 to 13,000 feet above MSL with values calculated at 300-foot increments. These studies included evaluation of upper air temperature structure and winds on Tract C-a and comparison to Grand Junction data. The results of these studies have been thoroughly documented (RBOSP, DDP 1976). A brief summary is presented here. For further information refer to the separate reports.

Upper air temperature profiles were analyzed to determine the relationship between the approximate stack height (300 feet) and the mixing layer height (normally taken as the upper extent of a surface based inversion or the base of an elevated inversion). Points H_1 and H_2 used in the analysis are defined in the idealized temperature profile illustrated in Figure 1.5 H_1 and H_1 are upper and lower tangential crossings, respectively, which represent different positions of the boundaries of the mixing layer. The mixing layer height is important because it determines the upper extent to which a buoyant plume can penetrate, if an elevated inversion is the top of the mixing layer height. In addition, for a surface based inversion, emissions discharged above the mixing layer height do not affect ground level concentrations.

Several cases observed during data analysis are shown schematically in Figure 1.6 to illustrate the relationships between H_1, H_2 and stack height, S. The value of stack height, S, was chosen as 300 feet based on the proposed facility plans. The seasonal average mixing layer heights

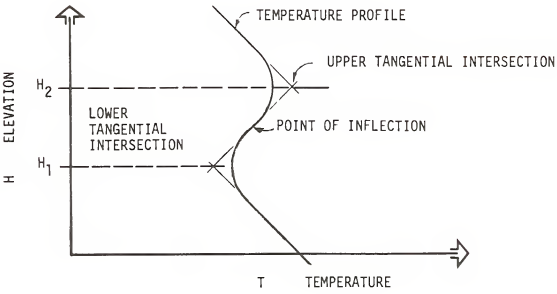

FIGURE 1.5

DETAILED TEMPERATURE PROFILE (IDEALIZED INVERSION)

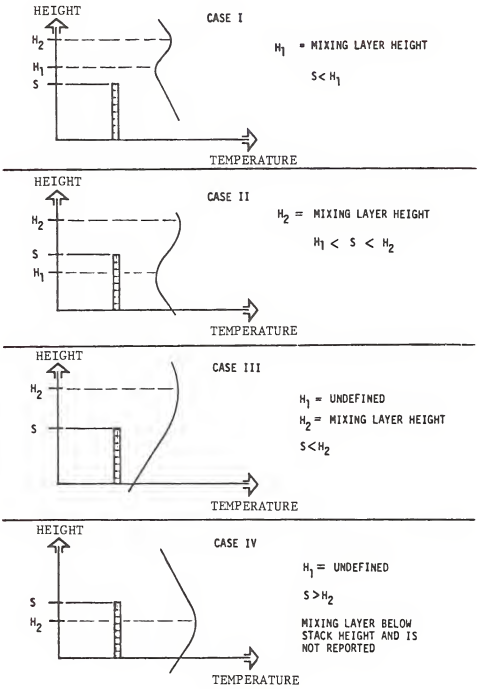

FIGURE 1.6

MIXING LAYER DETERMINATIONS

have been determined based upon morning and afternoon data (four soundings per day: Sites 1, 2, and 3 morning; and Site 4 afternoon) and are presented in Table 1.24. Also shown in this table are the mean times of inversion breakup for each season. These times were derived from temperature profiles in which a mixing layer existed during one sounding and did not exist in the next chronological sounding. The times of the two soundings were arithmetically averaged to define the mean time of inversion layer breakup for that day. Because the level used to reference H_1 and H_2 was chosen at 7,200 feet above MSL (elevation of proposed plant site at the time of these studies), it is possible to obtain negative values for H_1 AND H_2. This can only happen when the temperature structure of interest is contained entirely within the canyons below the level of Tract C-a. This phenomenon was observed in a significant number of cases; therefore, the average mixing layer heights in Table 3.1 would decrease if the reference level chosen for H_1 and H_2 were at the bottom of Piceance Creek Canyon (elevation 6,300 feet above MSL).

The mixing layer heights reported in Table 1.24 are not necessarily the heights of surface based inversions, but reflect altitudes of elevated inversions as well. To ensure that only significant mixing layers were included in the average height determination, an inversion had to be at least 200 feet deep with a total temperature change of at least 1.0 C from top to bottom of the interval.

The behavior of the mixing layer height by season shows that the first sounding during the summer and fall have a much lower mixing height than the corresponding soundings during the winter and spring. Average inversion breakup during the winter occurred at a significantly later time of the day than any of the other seasons, probably because of the reduced insolation available to "burn off" these inversions and the increased albedo (snow cover).

Winds aloft for this study are summarized in Table 1.25.

TABLE 1.24

SEASONAL AVERAGES - MIXING LAYER HEIGHT AND TIME TO INVERSION BREAKUP, RBOSP

	Average Mixing Layer Height for a 300 Ft Stack (Relative to 7200 Ft)[1/]								
	Sounding 1		Sounding 2		Sounding 3		Sounding 4		Mean Time To Inversion Breakup (MST)
Season	Height ft	Freq. of Occurrence	Height ft	Freq. of Occurrence	Height ft	Freq. of Occurrence	Height ft	Freq. of Occurrence	
Fall	642	0.67	400[2/]	0.09	--	--	--	--	7:50
Winter	2371	0.47	950	0.27	2900	0.13	2788	0.27	11:45
Spring	3067	0.20	--	--	--	--	--	--	6:50
Summer	588	0.20	--	--	--	--	--	--	7:00
Annual	1477		950				2788		

1/ Data only considered for inversions above level of tract (7,200 ft)

2/ Based on less than 3 occurrences

TABLE 1.25

SEASONAL AVERAGE WIND SPEED AND DIRECTION FOR SELECTED ALTITUDES, RBOSP

SEASON	AVERAGE WIND SPEED/DIRECTION AT						
	8000 ft	9000 ft	10000 ft	11000 ft	12000 ft	13000 ft	AVERAGE
Fall	4.22/247.60	7.27/246.64	8.83/260.96	12.31/261.04	12.26/263.40	14.47/269.10	9.81/260.78
Winter	17.80/243.89	22.18/248.77	26.72/257.38	27.93/269.34	29.47/273.98	30.29/278.04	25.15/264.01
Spring	9.21/220.20	11.57/224.26	13.39/229.00	19.73/227.48	17.36/237.07	19.89/242.04	15.07/231.56
Summer	2.40/271.20	2.80/278.02	3.93/279.86	5.15/273.34	6.14/275.79	7.15/275.39	4.59/275.64
Annual	8.17/239.81	10.64/243.78	12.78/252.54	15.42/255.67	15.70/262.51	17.33/266.16	13.18/255.60

Note: Units (MPH/Degrees)

CHAPTER 4 - AMBIENT AIR QUALITY OF THE STUDY AREA

I. DATA ACCUMULATION PROCEDURES

The air quality data acquisition system for RBOSP consists of four monitoring sites (Figure 1.2), each with trailer-contained air quality instrumentation; interface electronics; RF data telemetry links; and a central minicomputer at Site 1 for data storage and processing. Air quality parameters measured at each site are given below:

Site	Air Quality Parameter									
	THC	CH_4	SO_2	H_2S	NO_x	NO	CO	O_3	Particulates	Particulate Size
1	x	x	x	x	x	x	x	x	x	x
2	x	x	x	x					x	
3	x	x	x	x	x	x	x	x	x	
4	x	x	x	x					x	

Air Quality parameters are measured to:

- Determine background concentrations prior to any major development on Tract C-a;
- Provide data for comparison of observed levels with prevailing and proposed federal and state air quality standards;
- Aid in the interpretation and evaluation of diffusion model results and ecological studies; and
- Satisfy the Oil Shale Lease Stipulations.

The original lease stipulations (1974) state:

> ". . . in the collection of baseline data, the Lessee shall monitor air quality over at least 90 percent of each lease year, during which monitoring is required, using four strategically located stations. One of the stations shall be at the expected point of maximum concentration, or as close to that expected point of maximum concentration as feasible. The Lessee shall monitor air quality for sulfur dioxide, hydrogen sulfide, and suspended particulates, using automatic instruments with continuous recorders, when applicable. The Lessee shall also monitor, under the same conditions, hydrocarbons, oxides of nitrogen, and other pollutants, where the Area Oil Shale Supervisor has determined that such monitoring is necessary to determine baseline air quality or to conduct an effective monitoring program."

An Amendment of the Oil Shale Lease Serial Number C-20046, Tract C-a, was received by EG&G on December 8, 1976.

The amendment adds ozone and carbon monoxide to the list of air quality parameters for which data shall be collected. The amendment also redefines air quality and meteorology data quality and quantities as follows:

> "In the design and operation of the baseline data collection and monitoring programs, the Lessee shall strive to collect data for the greatest period of time practicable with emphasis on acquisition of quality data. The Lessee shall establish and implement a quality assurance program approved by the Mining Supervisor to assure high quality data collection. This quality assurance program shall include but not be limited to: quality control by standard reference materials, such as those available through National Bureau of Standards; data validation through established criteria of acceptability; method and frequency of calibration and maintenance; and testing programs to identify and quantify data anomalies."

II. BASELINE DATA SUMMARIES

A. Annual Summaries

Annual summaries of the air quality data collected, except particulate sizing and analytical trace element results, are presented for February 1975 through January 1976 and February 1976 through January 1977 in Tables 1.26 and 1.27. To summarize the two baseline years, a Biennial Summary is presented in Table 1.28.

There is very little variation between the annual mean values at a given site. This is qualified by an understanding of the Lower Detectable Limits (LDL) and accuracies of the measurement instruments (Table 1.29). The mean values of CO, NO, NO_x, H_2S, and SO_2, as seen in Table 1.26, are very nearly equal to or less than the LDL of the respective instrument. For example, for SO_2, Site 1, the first year's mean value (0.003 ppm) is 300 percent more than the second year's mean value (0.001 ppm). But, these values do not firmly indicate a presence of SO_2, since they are lower than the LDC (0.005 ppm) for the Bendix 8700X. On the average, for the two years of baseline data, measurable levels of CO, NO, NO_X, H_2S, and SO_2 were not present.

There appears to have been a general increase in THC and CH_4 annual mean values from the first to second baseline year, but the difference between these two values, NMHC, decreased during the second year. See section VI of this chapter.

Review of the annual maximum values for both years indicates higher individual particulate loading days at all sites except Site 3 during the first year. Maximum values of CO were higher for 1975-1976 than 1976-1977 although the difference has no sound significance.

A particulate size distribution summary for each year is presented in Table 1.30. The annual mean values indicate that numerically, practically all the airborne particulates are in the 0.0 to 0.95-micron size range for both years.

TABLE 1.26

ANNUAL SUMMARY OF AIR QUALITY PARAMETERS
(FEBRUARY 1975 THROUGH JANUARY 1976), RBOSP

Parameter	Units	Minimum[2]	Maximum[2]	Arithmetic Mean
		Site 1		
O_3	ppm	0.000	0.068	0.033
CO	ppm	0.000	4.213	0.770
NO	ppm	0.000	0.061	0.004
NO_x	ppm	0.000	0.099	0.005
CH_4	ppm	0.123	1.586	1.316
THC	ppm	1.055	1.916	1.431
H_2S	ppm	0.000	0.027	0.001
SO_2	ppm	0.000	0.057	0.003
Particulates	$\mu g/m^3$	<1[4]	211[3]	9[1]
		Site 2		
CH_4	ppm	0.058	1.864	1.307
THC	ppm	0.244	2.367	1.461
H_2S	ppm	0.000	0.034	0.002
SO_2	ppm	0.000	0.041	0.002
Particulates	$\mu g/m^3$	<1[3]	102[3]	9[1]
		Site 3		
O_3	ppm	0.000	0.089	0.030
CO	ppm	0.000	5.959	0.802
NO	ppm	0.000	0.159	0.005
NO_x	ppm	0.000	0.154	0.006
CH_4	ppm	1.015	2.355	1.396
THC	ppm	1.146	2.913	1.500
H_2S	ppm	0.000	0.012	0.002
SO_2	ppm	0.000	0.023	0.001
Particulates	$\mu g/m^3$	1[3]	247[3]	18[1]
		Site 4		
CH_4	ppm	0.463	1.902	1.329
THC	ppm	0.680	2.343	1.423
H_2S	ppm	0.001	0.065	0.005
SO_2	ppm	0.000	0.060	0.007
Particulates	$\mu g/m^3$	<1[3]	469[3]	13[1]

1/ Geometric Mean
2/ Hourly Average
3/ Calculated from 24-hr batch sample
4/ LDL of particulate measurement technique

TABLE 1.27

ANNUAL SUMMARY OF AIR QUALITY PARAMETERS
(FEBRUARY 1976 THROUGH JANUARY 1977), RBOSP

Parameter	Units	Minimum[2]	Maximum[2]	Arithmetic Mean
		Site 1		
O_3	ppm	0.016	0.060	0.035
CO	ppm	0.000	1.555	0.329
NO	ppm	0.000	0.237	0.012
NO_x	ppm	0.000	0.234	0.012
CH_4	ppm	1.005	2.006	1.463
THC	ppm	1.048	2.422	1.559
H_2S	ppm	0.000	0.047	0.001
SO_2	ppm	0.000	0.092	0.001
Particulates	$\mu g/m^3$	<1[4]	81[3]	8[3]
		Site 2		
CH_4	ppm	1.117	1.565	1.393
THC	ppm	1.178	2.251	1.461
H_2S	ppm	0.001	0.013	0.002
SO_2	ppm	0.000	0.008	0.000
Particulates	$\mu g/m^3$	<1[4]	57[3]	9[1]
		Site 3		
O_3	ppm	0.002	0.068	0.032
CO	ppm	0.000	1.826	0.447
NO	ppm	0.000	0.103	0.006
NO_x	ppm	0.000	0.099	0.006
CH_4	ppm	0.755	1.667	1.432
THC	ppm	0.740	1.810	1.451
H_2S	ppm	0.000	0.034	0.003
SO_2	ppm	0.000	0.049	0.003
Particulates	$\mu g/m^3$	<1[4]	281[3]	12[1]
		Site 4		
CH_4	ppm	0.946	1.661	1.409
THC	ppm	0.994	1.947	1.465
H_2S	ppm	0.000	0.075	0.004
SO_2	ppm	0.000	0.095	0.005
Particulates	$\mu g/m^3$	<1[4]	182[3]	12[1]

[1] Geometric Mean
[2] Hourly Average
[3] Calculated from 24-hr batch sample
[4] LDL of particulate measurement technique

TABLE 1.28

BIENNIAL SUMMARY OF AIR QUALITY PARAMETERS
(FEBRUARY 1975 THROUGH JANUARY 1977), RBOSP

Parameter	Units	Minimum[2]	Maximum[2]	Arithmetic Mean
		Site 1		
O_3	ppm	0.000	0.068	0.034
CO	ppm	0.000	4.213	0.550
NO	ppm	0.000	0.237	0.008
NO_x	ppm	0.000	0.234	0.009
CH_4	ppm	0.123	2.006	1.385
THC	ppm	1.055	2.422	1.500
H_2S	ppm	0.000	0.047	0.001
SO_2	ppm	0.000	0.092	0.002
Particulates	$\mu g/m^3$	<1[4]	211[3]	9[1]
		Site 2		
CH_4	ppm	0.058	1.864	1.350
THC	ppm	0.244	2.367	1.461
H_2S	ppm	0.000	0.034	0.002
SO_2	ppm	0.000	0.041	0.001
Particulates	$\mu g/m^3$	1[3]	102[3]	9[1]
		Site 3		
O_3	ppm	0.000	0.089	0.031
CO	ppm	0.000	5.959	0.625
NO	ppm	0.000	0.159	0.006
NO_x	ppm	0.000	0.154	0.006
CH_4	ppm	1.015	2.355	1.414
THC	ppm	1.146	2.913	1.480
H_2S	ppm	0.000	0.034	0.003
SO_2	ppm	0.000	0.049	0.002
Particulates	$\mu g/m^3$	1[3]	281[3]	15[1]
		Site 4		
CH_4	ppm	0.463	1.902	1.369
THC	ppm	0.680	2.343	1.440
H_2S	ppm	0.000	0.075	0.005
SO_2	ppm	0.000	0.095	0.006
Particulates	$\mu g/m^3$	1[3]	469[3]	13[1]

[1] Geometric Mean
[2] Hourly Average
[3] Calculated from 24-hr batch sample
[4] LDL of particulate measurement technique

TABLE 1.29

AIR QUALITY INSTRUMENTATION AND MEASUREMENT TECHNIQUES, RBOSP.

Parameter	Manufacturer	Model	Technique	Lower Detectable Limit (ppm)3/	Accuracy ± (ppm)
SO_2/H_2S	Bendix	8700X	Flame photometric with separation column for SO_2 and H_2S	0.005	0.020 3/
NO_x/NO	Bendix	8101-B	Chemiluminescence	0.005	0.010 3/
THC/CH_4	Bendix	8201	Flame ionization detector with separation column for CH_4	0.005	0.10 (THC) 3/ 0.02 (CH_4) 3/
Photochemical Oxidant (O_3) 1/	Bendix	8002	Chemiluminescence	0.001	0.004 2/
CO	Bendix	8501-5CA	Nondispersive infrared detection	0.5	0.500 2/

1/ Photochemical oxidant corrected for interference due to nitrogen oxide and nitrogen dioxide as measured by the Federal Reference Method as Ozone (O_3) by the chemiluminescence method.

2/ Estimated accuracy (Bendix)

3/ Bendix Manual for instruments (1973a, 1973b, 1973c, 1973d, 1974)

TABLE 1.30

ANNUAL SUMMARIES OF SIZE DISTRIBUTION
OF PARTICULATES AT SITE 1, RBOSP

SEASON	Number of Data Points	PARTICULATE CONCENTRATION BY PARTICLE SIZE[1/] RANGE				
		7.2-∞ microns	3.0-7.2 microns	1.5-3.0 microns	0.95-1.5 microns	0-0.95 microns
		April 1975 - February 1976				
Spring	3	<1	<1	<1	<1	9
Summer	8	<1	<1	<1	<1	12
Fall	8	<1	<1	<1	<1	7
Winter	7	<1	<1	<1	<1	2
Mean		<1	<1	<1	<1	7
Total	26					
		March 1976 - January 1977				
Spring	8	1	2	1	1	8
Summer	16	1	1	<1	<1	12
Fall	8	1	1	<1	<1	16
Winter	6	<1	<1	<1	<1	4
Mean		1	1	<1	<1	12
Total	38					
Two Year Mean	64	<1	<1	<1	<1	10

1/ "Equivalent Aerodynamic Diameter" is defined as the size of a spherical particle of density 1 gm/cc, which has the same terminal settling velocity as the sampled particle.

Trace element analysis of high volume filters shows that collected particulates consist primarily of silicon, aluminum, magnesium, copper, iron, and calcium. All these materials are currently found in natural ground surface material. Particles in these small size ranges are most easily dislodged by the wind friction along the ground surface. Suspended atmospheric particulates in the size range of one micrometer or less contribute to atmospheric haze and are deposited in the lower respiratory tract of humans when inhaled. Particulate size distributions in air samples taken in Death Valley, California show very small percentages of particulates larger than one micrometer, similar to the size distribution measured on Tract C-a. Urban air suspended particulate size distributions show that particle sizes from 0.1 to 1.0 micrometer account for the greatest mass fraction of the total weight of particulates suspended in the lower atmosphere.

High volume filter and analytical trace element results for both years are presented in Tables 1.31 and 1.32.

Mean values of hydrocarbons and ozone at all sites indicate diurnal variations and are significantly above the LDL of the respective analyses (Figures 1.7, 1 8, and 1.9). Several sources (Halligan 1975, Muller et al. 1964, Geissman and Irwin 1974) indicate that local vegetation can contribute significant amounts of hydrocarbons to the atmosphere. The percentage of hydrocarbon values resulting from such sources is, however, unknown. The fact that NMHC data has a standard deviation comparable to the NAAQS should not be overlooked in interpreting these results. The effort of trying to define the source of ozone is inconclusive.

B. Comparisons Between Sites and Parameters

Comparisons between sites and parameters with recognizable significance are presented in this section. A review of Figures 1.7 and 1.8 shows a strong amplitude and time dependence between CH_4 and THC. This indicates that methane is a large portion of the total hydrocarbons in the Tract C-a vicinity. Site 3 and 4 indicate larger diurnal variations than Sites

TABLE 1.31

HIGH VOLUME FILTER ANALYTICAL TRACE ELEMENT RESULTS
(FEBRUARY 1975 THROUGH JANUARY 1976), RBOSP

	Concentration (ng/m³)			
Parameter	Spring	Summer	Fall	Winter
Uranium	<0.03	I.S.	<0.05	0.29
Thorium	<0.03	<0.03	0.15	0.07
Bismuth	<0.03	<0.03	0.13	0.03
Lead	11.93	5.04	3.18	2.52
Thallium	<0.03	<0.03	0.12	<0.03
Mercury	NR	0.03	0.05	0.08
Gold	<0.03	<0.03	<0.03	<0.03
Platinum	<0.03	<0.03	<0.03	<0.03
Iridium	<0.03	<0.03	<0.03	<0.03
Osmium	<0.03	<0.03	<0.03	<0.03
Rhenium	I.S.	I.S.	I.S.	I.S.
Tungsten	<0.03	<0.03	<0.10	<0.03
Tantalum	<0.03	<0.03	0.61	<0.03
Hafnium	<0.03	<0.03	<0.03	<0.03
Lutecium	<0.03	<0.03	<0.03	<0.03
Ytterbium	<0.03	<0.03	<0.03	<0.03
Thulium	<0.03	<0.03	<0.03	<0.03
Erbium	<0.03	<0.03	<0.03	<0.03
Holmium	<0.03	<0.03	<0.03	<0.03
Dysprosium	<0.03	NR	<0.03	<0.03
Terbium	<0.03	NR	<0.03	<0.03
Gadolinium	<0.03	NR	<0.03	<0.03
Europium	<0.03	NR	<0.03	<0.03
Samarium	<0.03	NR	<0.03	<0.03
Neodymium	<0.03	NR	0.07	<0.03
Praseodymium	<0.03	0.06	0.19	<0.03
Cerium	0.93	2.92	0.82	0.10
Lanthanium	0.42	0.74	0.21	0.14
Barium	5.57	14.84	9.01	1.70
Cesium	<0.03	0.04	<0.03	<0.03
Iodine	<0.03	<0.03	0.07	<0.03
Tellurium	<0.03	<0.03	<0.03	<0.03
Antimony	<0.03	0.07	0.04	0.07
Tin	0.25	1.35	0.17	0.23
Indium	I.S.	I.S.	I.S.	I.S.
Cadmium	<0.03	<0.03	0.03	<0.03
Silver	<0.03	<0.03	0.12	<0.03
Palladium	<0.03	<0.03	<0.03	<0.03
Rhodium	<0.03	<0.03	<0.03	<0.03
Ruthenium	<0.03	<0.03	<0.03	NR
Molybdenum	5.04	3.45	<0.53	0.19
Niobium	0.13	0.37	0.29	0.12
Zirconium	0.58	1.48	1.54	0.25
Yttrium	0.24	0.56	0.17	0.05
Strontium	3.18	3.18	10.07	0.93
Rubidium	1.11	2.52	1.48	0.15
Bromine	0.48	<0.42	0.08	0.21
Selenium	<0.03	0.10	0.40	0.06
Arsenic	0.27	<0.16	1.06	0.64
Germanium	<0.03	<0.03	<0.03	<0.03
Gallium	<0.03	0.45	0.48	<0.03
Zinc	<0.03	9.54	2.92	15.37
Copper	20.14	124.55	45.05	45.05
Nickel	<0.03	19.88	2.04	1.54
Cobalt	NR	4.86	0.22	0.06
Iron	NR	371	901	NR
Manganese	NR	<10.07	24.12	1.78
Chromium	NR	<7.42	5.57	1.78
Vanadium	1.40	1.70	2.92	1.54
Titanium	100.70	135.15	172.30	11.13
Scandium	<0.03	0.11	0.11	<0.03
Calcium	450	927.50	2650	204.05
Potassium	583	328.60	1590	119.25
Chlorine	11.40	17.76	1.27	8.22
Sulphur	140.45	137.80	174.90	42.4
Phosphorus	21.73	45.05	212	34.45
Silicon	1272	19875	21730	NR
Aluminum	177.55	556.50	3710	NR
Magnesium	254.40	397.50	1113	60.95
Sodium	High Blank	196.10	530.06	76.85
Fluorine	111.3	16.43	90.10	18.82
Oxygen	NR	NR	NR	NR
Nitrogen	NR	NR	NR	NR
Carbon	NR	NR	NR	NR
Boron	<0.03	NR	NR	NR
Beryllium	<0.03	<0.03	<0.05	<0.03
Lithium	1.33	*9.81	0.72	0.27

NR - Not reported
IS - Internal standard

TABLE 1.32

HIGH VOLUME FILTER ANALYTICAL TRACE ELEMENT RESULTS
(FEBRUARY 1976 THROUGH JANUARY 1977), RBOSP

Parameter	Concentration (ng/m³)			
	Spring	Summer	Fall	Winter
Uranium	<0.03	<0.05	0.04	0.06
Thorium	<0.03	<0.06	0.22	0.18
Bismuth	0.07	0.08	0.18	0.03
Lead	1.09	8.7	6.3	5.9
Thallium	<0.03	<0.05	<0.05	<0.12
Mercury	<0.00	<0.027	<0.023	<0.07
Gold	<0.03	<0.03	<0.02	<0.05
Platinum	<0.03	<0.03	<0.05	<0.14
Iridium	<0.03	<0.03	<0.03	<0.08
Osmium	<0.03	<0.03	<0.04	<0.12
Rhenium	I.S.	I.S.	I.S.	I.S.
Tungsten	<0.03	0.09	0.07	<0.13
Tantalum	<0.03	0.12	0.04	0.11
Hafnium	<0.03	<0.17	<0.09	<0.26
Lutecium	<0.03	<0.03	<0.02	<0.04
Ytterbium	<0.03	<0.13	<0.08	<0.13
Thullium	<0.03	<0.03	0.01	<0.03
Erbium	<0.03	<0.03	0.01	<0.14
Holmium	<0.03	<0.03	<0.01	<0.03
Dysprosium	<0.03	<0.04	0.05	<0.05
Terbium	<0.03	<0.03	<0.01	<0.03
Gadolinium	<0.03	<0.03	<0.01	<0.10
Europium	<0.03	<0.03	<0.01	<0.08
Samarium	<0.03	<0.13	0.05	<0.06
Neodymium	0.13	1.0	0.74	<0.48
Praseodymium	0.04	0.21	0.21	0.05
Cerium	0.14	0.87	1.3	0.07
Lanthanium	0.06	0.78	0.83	0.06
Barium	2.92	13	14	1.8
Cesium	<0.03	0.34	0.10	<0.01
Iodine	<0.03	0.08	<0.01	<0.04
Tellurium	<0.03	<0.03	0.01	<0.01
Antimony	⅟	0.04	<0.02	0.07
Tin	0.265	0.76	0.20	⅟
Indium	I.S.	I.S.	I.S.	I.S.
Cadmium	0.04	0.06	0.04	<0.01
Silver	0.03	0.11	0.03	<0.01
Palladium	<0.03	<0.03	<0.04	<0.10
Rhodium	<0.03	<0.03	<0.01	<0.03
Ruthenium	<0.03	<0.03	<0.03	<0.08
Molybdenum	0.05	0.24	1.3	0.62
Niobium	0.03	0.36	0.44	0.02
Zirconium	0.17	0.47	1.5	0.16
Yttrium	0.05	0.64	0.31	0.09
Strontium	3.98	4.6	4.5	1.0
Rubidium	0.45	1.7	1.9	0.28
Bromine	0.05	1.8	<0.01	0.11
Selenium	0.03	0.10	0.14	0.03
Arsenic	0.16	1.3	4.7	1.2
Germanium	<0.03	<0.03	0.03	<0.01
Gallium	<0.03	0.14	0.08	<0.01
Zinc	7.95	5.0	4.9	3.9
Copper	34.45	16	28	7.2
Nickel	0.11	4.0	0.39	0.17
Cobalt	0.03	0.48	0.06	0.15
Iron	188.15	250	850	130
Manganese	2.92	6.6	11	0.21
Chromium	1.09	0.82	⅟	⅟
Vanadium	0.53	2.0	3.9	0.19
Titanium	12.99	130	23	15
Scandium	<0.03	<0.03	0.04	<0.15
Calcium	=344.5	620	=2400	220
Potassium	=318.0	550	=1100	48
Chlorine	1.99	5.0	4.1	⅟
Sulphur	16.96	20	71	26
Phosphorus	37.10	49	110	⅟
Silicon	2650	870	=14000	670
Aluminum	477	=2100	770	430
Magnesium	135.15	81	920	120
Sodium	53.0	36	350	94
Fluorine	9.54	19	81	0.87
Oxygen	NR	NR	NR	NR
Nitrogen	NR	NR	NR	NR
Carbon	NR	NR	NR	NR
Boron	NR	NR	NR	NR
Beryllium	<0.03	<0.03	0.01	<0.01
Lithfun	2.49	0.16	7.2	1.9

[1] Samples are collected on cellulose filters and analyzed by spark source mass spectrometry.
[2] Blank level higher than sample
[3] Not reported due to blank level
* Possible source contamination
NR - Not reported
IS - Internal Standard

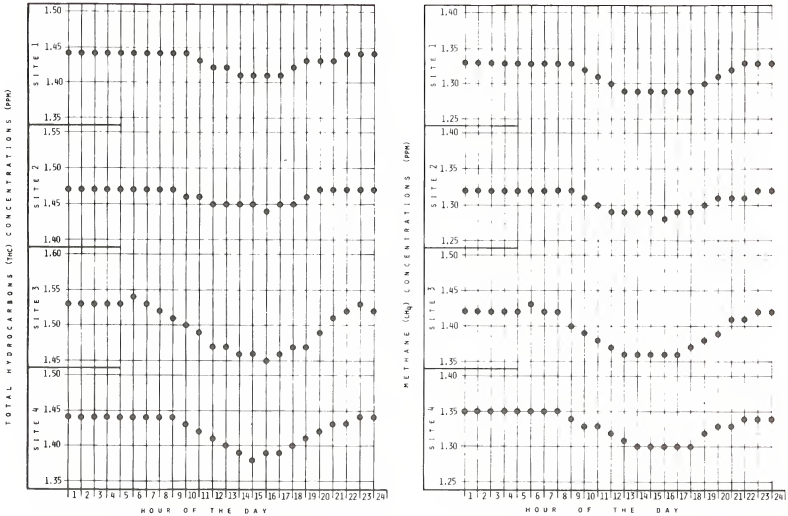

FIGURE 1.7

DIURNAL VARIATIONS OF MEAN VALUES OF METHANE AND TOTAL HYDROCARBONS AT SITES 1, 2, 3, AND 4 (FEBRUARY 1975 THROUGH JANUARY 1976), RBOSP

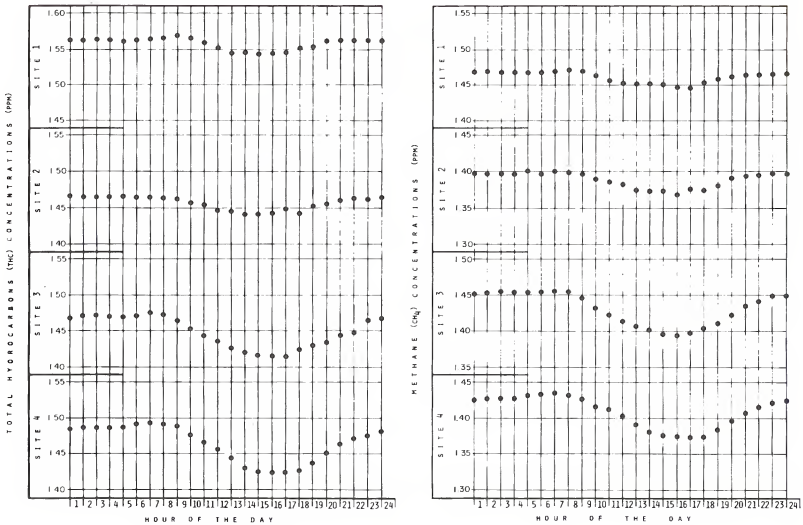

FIGURE 1.8

DIURNAL VARIATIONS OF MEAN VALUES OF METHANE AND TOTAL HYDROCARBONS AT SITES 1, 2, 3, AND 4 (FEBRUARY 1976 THROUGH JANUARY 1977), RBOSP

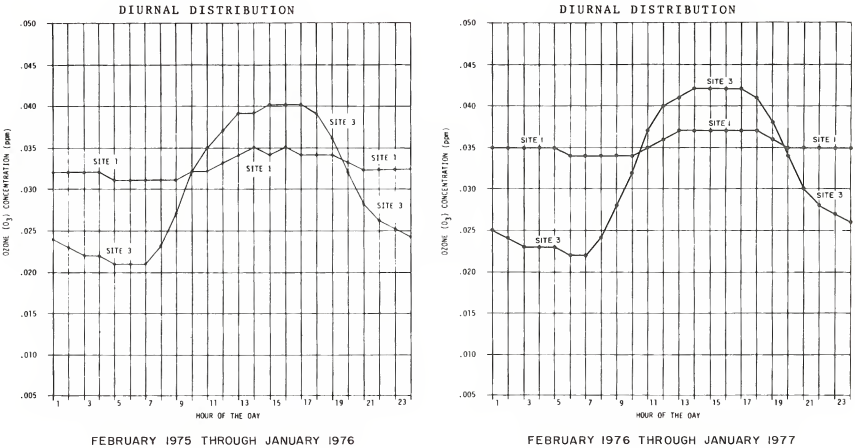

FIGURE 1.9

DIURNAL VARIATION OF MEAN OZONE CONCENTRATIONS MEASURED AT SITES 1 AND 3 FOR EACH BASELINE YEAR, RBOSP

1 and 2 for both years. Diurnal variations were not expected on the basis of previous literature. However, similar variations were noted on other shale tracts. Sites 3 and 4 are gulches where there is a greater amount of vegetative ground cover than at Sites 1 and 2. For all cases in these figures, the mean values of THC and CH_4 (except Site 1 for both years) decrease during the 6-9 a.m. period. This 6-9 a.m. period is the applicable time frame of the Federal non-methane hydrocarbon (NMHC) regulation. This and other applicable standards are discussed in Section III of this chapter. NMHC is obtained by a THC minus CH_4 calculation of individual respective hourly data points, only. Therefore variations in the rate of decrease of THC and CH_4 in individual 6-9 a.m. periods could produce exceedences. The cause of this decrease has not been defined at this point. A special field effort to define this decrease and individual analyzer THC and CH_4 response times might add pertinent information in defining NMHC exceedences.

The relative magnitude of the diurnal variation of ozone at Site 3 is larger than at Site 1; however, the time intervals at both sites over which changes took place correspond closely. Although slight amplitude differences exist from 1975-1976 to 1976-1977, year to year diurnal trends are almost identical.

Because of regulatory agency emphasis on present ozone concentrations and further development in the "oil shale area," a special case study was performed for ozone data collected at Tract C-a. This analysis was performed on Winter 1976-1977 data with emphasis on variations in both space and time. The remainder of the two-year baseline data base was reviewed for confirmation of special study conclusions. This review indicated that the overall conclusions reached for the special case study are representative for the two-year data base.

Figure 1.9 shows the yearly diurnal variations of the mean ozone values. These mean variations are similar to those discussed below for the special case of minimum and maximum values for the Winter 1976-1977 quarter. Therefore, this special study appears to be representative of the two-year ozone data base.

Tabulations of the frequency of occurrence by hour of the day of the daily maximum and minimum values of ozone concentration as measured at Sites 1 and 3 (RBOSP) were constructed. The results (Table 1.33) were analyzed for consistency between sites and between adjacent hours of a given day. In general, the primary observed anomaly was that only a slight normal diurnal variation was noted at Site 1. The Site 3 data appeared to be more consistent with those experienced elsewhere, in that they exhibited a diurnal range of approximately 0.015 to 0.020 ppm, or about 50-67 percent of average peak value, as contrasted with the observations taken at Site 1, where the diurnal range was as small as 0.003-0.007 ppm. Furthermore, the Site 3 data exhibited diurnal variations, with the morning minimum and early afternoon maximum as shown in the table. This year's baseline summary, Figure 1.9, indicates this maximum occurring at mid-afternoon. The Site 1 data showed only a small afternoon maximum. The strongly marked minimum is evident for Site 3 data. Efforts to define this descrepency between the two sites, which are separated by only about two miles of fairly rough terrain and about 800 feet in elevation did not give conclusive results.

The RBOSP Tract C-a is located far from any large sources of precursor emissions (usually considered to be non-methane hydrocarbons, NMHC, and oxides of nitrogen, NO_x). June, July and August are ordinarily the peak months for oxidants. Even though ozone concentrations are lower during the "off-season" at most locations, the summer-time levels at the RBOSP sites were not much higher: maximum reported levels were 0.056 to 0.068 ppm at Sites 1 and 3, respectively, during the summer of 1976.

TABLE 1.33

FREQUENCY OF OCCURRENCE OF DIURNAL MINIMUM AND MAXIMUM OZONE CONCENTRATION AT RBOSP SITES 1 AND 3, BY HOUR OF THE DAY, WINTER 19/6-77

HOUR	Number of Times Daily Minimum and Maximum Occurred at this Hour							
	Site 1				Site 3			
	Minimum		Maximum		Minimum		Maximum	
	N	%*	N	%	N	%	N	%
0000	3	2.88	8	7.84	3	2.91	0	0.00
0100	3	2.88	5	4.90	8	7.77	0	0.00
0200	2	1.92	4	3.92	10	9.71	0	0.00
0300	2	1.92	3	2.94	9	8.74	1	0.85
0400	4	3.85	4	3.92	10	9.71	0	0.00
0500	8	7.69	4	3.92	9	8.74	0	0.00
0600	7	6.73	4	3.92	13	12.62	0	0.00
0700	6	5.77	3	2.94	8	7.77	0	0.00
0800	8	7.69	6	5.88	9	8.74	0	0.00
0900	5	4.81	1	0.98	0	0.00	0	0.00
1000	10	9.62	1	0.98	0	0.00	0	0.00
1100	4	3.85	1	0.98	0	0.00	0	0.00
1200	4	3.85	3	2.94	0	0.00	4	3.42
1300	1	0.96	8	7.84	0	0.00	15	12.82
1400	1	0.96	11	10.78	0	0.00	28	23.93
1500	0	0.00	7	6.86	0	0.00	36	30.77
1600	2	1.92	4	3.92	0	0.00	28	23.93
1700	5	4.81	3	2.94	0	0.00	4	3.42
1800	7	6.73	1	0.98	0	0.00	0	0.00
1900	4	3.85	3	2.94	1	0.97	1	0.85
2000	1	0.96	3	2.94	3	2.91	0	0.00
2100	5	4.81	4	3.92	4	3.88	0	0.00
2200	4	3.85	5	4.90	4	3.88	0	0.00
2300	8	7.69	6	5.88	12	11.65	0	0.00
Totals	104	100.00	102	99.96	103	100.00	117	99.99
N_m (days):	3		3		5		5	
N_{ht} (days):	8		15		0		0	

*Percent of total.

N_m is defined as the number of days having six or more hours of missing data.

N_{ht} is defined as the number of days having the same peak concentration reported for six or more hours during the same day.

The smaller range in the ozone data from Site 1 was present in the Summer Quarter also, as evidenced by the fact that while the two mean values are almost identical (0.035 and 0.036 ppm, respectively), the reported minimum concentration at Site 1 was over three times as high as that from Site 3, while the Site 1 maximum was lower than the Site 3 maximum by 17.6 percent (of the higher value). The maxima and minima for the Winter Quarter of 1975-1976 were almost identical to those found during Winter Quarter 1976-1977, while the values for the Spring Quarter of 1976 were intermediate between those for the previous winter and the 1976 summer data. In each case the same relationship of magnitudes fo the ranges was observed to hold. From the above discussion and the data presented in Table 1.33 it can be seen that at no time during the year, 1 February 1976 to 31 January 1977, was the National Ambient Air Quality Standard (NAAQS) for photochemical oxidants such as ozone exceeded, although the data for the previous year show that it was exceeded five times during that period (at Site 3 only).

Even the highest value reported during the entire two-year study period was not much over the standard (0.089 ppm, reported at Site 3 at 1900 hours on 29 August 1975). The reasons for measured oxidant levels above the NAAQS are not well known; similar situations have been reported throughout the country. EPA and others have the problem under study at present.

Suspended particulate measurements obtained during the baseline data period occasionally approached or exceeded some air quality standards. Correlation between particulate levels and windspeed averages can be shown (at the 99 percent confidence level) as can a correlation between particulate level and relative humidity. A multi-variate correlation between particulate, windspeed, and humidity, however, was relatively weak.

Particulate measurements during the baseline data period were obtained from Hi-volume samplers mounted at ground level (filter located 1.5 m above ground). Late in the baseline data acquisition program, Hi-volume samplers were installed above the surface where the collection filters were placed 7 m high. The elevated particulate collection is less than the surface collected values 45 percent of the time. This indicates a tendencey to include particles with high settling velocities at the lower of the two Hi-volume samplers. These particles tend to be generally larger than 10μ and are thus non-respirable.

Since there are no local sources of SO_2, NO, NO_x, or CO, these pollutants must be of natural origin or transported into the region by the continental air mass movement. A correlation was attempted to determine whether this combination of atmospheric pollutants was related to regional air mass movement. The correlation could not be developed because average pollutant concentration levels for the subject pollutants were below the threshold of detection limits established by the Federal EPA for this instrumentation. Under these conditions EPA Quality Assurance Guidelines recommend substituting a constant value (50 percent of instrument threshold) for the variable.

Visibility has been measured from Tract C-a by both qualitative and quantitative procedures. A significant factor in visibility is haze due to the presence of water vapor in the atmosphere. The water vapor scatters light and reduces visual range. Visual range reduction can also occur due to the presence of suspended particulate matter in the atmosphere. Another factor may be the presence of oxidizing chemicals (ozone) which convert atmospheric chemical components into particulate matter (sulfates or nitrates). A multi-variate regression analysis of visibility data versus humidity, particulates, and ozone data was performed. The results are that neither the measured particulate concentration, nor the measured ozone concentration were significant contributors to a reduction in visual range.

Two additional correlation attempts were made. One to develop a measure of the relationship between ozone concentration and synoptic weather, and the other to determine whether total hydrocarbon concentration in the ambient air was related to ground cover. Neither of these correlations were successful because of insufficent data.

III. COMPARISON OF TRACT AMBIENT AIR QUALITY AND STATE AND FEDERAL REGULATIONS

A review was made of federal and state air quality regulations to identify those pertinent for evaluating the background air quality measurements made on Tract C-a (see list of references). Reports of investigations performed in the area around Tract C-a as well as federal and state publications that deal with oil shale development were also reviewed to obtain additional information, especially concerning anticipated air quality impacts of oil shale development.

Development of Tract C-a is subject to federal and state control and regulation. Some of the requirements are specific to oil shale development while others are general for control of air quality impacts from a wide range of sources. Federal and state regulations and stipulations which may be applicable during the development of Tract C-a are described below.

According to Section 109 of the Clean Air Act, as amended, ..."National primary ambient air quality standards define levels of air quality which the Administrator judges are necessary, with an adequate margin of safety, to protect the public health. National secondary ambient air quality standards define levels of air quality which the Administrator judges necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant." Section 302(h) of the Clean Air Act defines such effects as including, but not limited to, "effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility, climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being. Current standards for pollutants for which ambient air standards have been established are presented in Table 1.34.

TABLE 1.34

NATIONAL AMBIENT AIR QUALITY STANDARDS[1/] (40 CFR PART 50)

Substance	Averaging Time	Standard			
		Primary[2/]		Secondary[3/]	
		μg/m^3	ppm	μg/m^3	ppm
Sulfur Oxides (Sulfur Dioxide)	Annual arithmetic mean	80	0.03	None	---
	24-hour maximum	365	0.14	None	---
	3-hour maximum	None	---	1,300	0.5
Particulate Matter[4/]	Annual geometric mean	75	NA	60	NA
	24-hour maximum	260	NA	150	NA
Carbon Monoxide					
	8-hour maximum	10,000	9	10,000	9
	1-hour maximum	40,000	35	40,000	35
Hydrocarbons[6/] (corrected for methane)	3-hour maximum (6-9 am)	160	0.24	160	0.24
Nitrogen Dioxide[7/]	Annual arithmetic mean	100	0.05	100	0.05
Photochemical Oxidants[5/] (corrected for NO_x and SO_2)	1-hour maximum	160	0.08	160	0.08

1/ All standards (other than annual standards) are specified as not to be exceeded more than once per year. The measurement methods are also specified as Federal Reference Methods.

2/ Set for the protection of health.

3/ Set for the protection of welfare.

4/ The secondary annual standard (60 μg/m^3) is a guide to be used in assessing implementation plans to achieve the 24-hour secondary standard.

5/ Expressed as ozone by the Federal Reference Method.

6/ This NAAQS is for use as a guide in devising implementation plans to achieve oxidant standards.

7/ No Federal Reference Method currently in effect.

Source: United States Environmental Protection Agency, 1971, 1973, 1975, 1976.

The EPA promulgated in 1974, at the direction of the courts, regulations to ensure that there is "no significant deterioration" in air quality in terms of SO_2 and suspended particulates for those areas of the country which do not presently exceed the National Ambient Air Quality Standards. Section 52.21(c) of these regulations establishes the maximum allowable incremental concentration of a pollutant over existing background levels by area class designation. Three classes, I, II, and III are defined with all areas of the country presently being classified as Class II. Redesignations may be proposed by the applicable State or Federal Land Manager or Indian Governing Body having jurisdiction over the area to be redesignated. The maximum allowable incremental concentrations of pollutants for Class I and Class II areas are presented in Table 1.35. Class I areas are those considered pristine. Class III areas may not have increases in ambient air concentrations of SO_2 and suspended particulates which result in ambient concentrations greater than the National Ambient Air Quality Standards.

Environmental stipulations were incorporated into the Tract C-a lease by the United States Bureau of Land Management (BLM) in 1974 to ensure that appropriate measures are taken to prevent pollution of the environment. These stipulations require environmental baseline monitoring, mitigating procedures, and operational monitoring to ensure that pollution is minimized and where possible avoided. Specifically relating to background monitoring the stipulations say:..."in the collection of baseline data, the Lessee shall monitor air quality over at least 90% of each lease year, during which monitoring is required, using four strategically located stations. One of the stations shall be at the expected point of maximum concentrations, or as close to that expected point of maximum concentration as feasible. The Lessee shall monitor air quality for sulfur dioxide, hydrogen sulfide, and suspended particulates, using automatic instruments with continuous recorders, when applicable. The Lessee shall also monitor, under the same conditions, hydrocarbons, oxides of nitrogen, and other pollutants, where the mining supervisor has determined that such monitoring is necessary to determine baseline air quality or to conduct an effective monitoring program."

TABLE 1.35

MAXIMUM ALLOWABLE INCREMENTS OF SELECTED POLLUTANTS FOR AREA CLASSES AS ESTABLISHED BY SIGNIFICANT DETERIORATION REGULATIONS (40 CFR PART 52)

Pollutant	Class I $\mu g/m^3$	Class II $\mu g/m^3$
Particulate matter:		
Annual geometric mean	5	10
24-hr maximum	10	30
Sulfur dioxide:		
Annual arithmetic mean	2	15
24-hr maximum	5	100
3-hr maximum	25	700

Class III area concentrations are not to exceed the National Ambient Air Quality Standards. Source: United States Environmental Protection Agency 1974.

TABLE 1.36

STATE OF COLORADO SUSPENDED PARTICULATE MATTER AMBIENT AIR STANDARDS FOR DESIGNATED AND NON-DESIGNATED AREAS

Suspended Particulate Matter 1/	Non-Designated Areas	Metro-Denver Air Quality Control Region, and Designated State Areas		
		1973	1976	1980
Short Term 2/ ($\mu g/m^3$)	150	200	180	150
Long Term 3/ ($\mu g/m^3$)	45	70	55	45

1/Measured at ambient conditions.
2/A 24-hour maximum of any 24-hour period and must not be exceeded more than once in a 12-month period.
3/Long Term Level - An annual arithmetic mean of all 24-hour concentrations.

Source: Colorado Air Pollution Control Commission 1970.

Enforcement of state air quality standards falls under the jurisdiction of the Colorado Air Pollution Control Division of the Colorado Department of Health. The Piceance Creek basin was designated in 1974 in the Colorado State Implementation Plan as being in the Colorado-Utah Oil Shale Interstate Air Quality Maintenance Area. Through designation of the entire region as a maintenance area, the state identifies it as having the potential for violation of particulates, SO_2, CO, or O_3 standards within the next 10 years. The state is divided into "designated" and "nondesignated" areas for suspended particulate matter. "Designated" areas are Standard Metropolitan Statistical Areas (SMSA's), which are primarily population and industrial centers. Other areas of the state primarily rural, are considered "nondesignated" areas. The ambient air standards for designated and nondesignated areas for particulate matter are shown in Table 1.36. Figure 1.10 includes the Utah portion of the Oil Shale Interstate AQMA Figure 1.11 shows the two air quality regions of interest.

In 1975 the Colorado Air Pollution Control Commission promulgated regulations based on an incremental approach for controlling ambient levels of SO_2 in areas of the state. Area identifications are based on a modification of designated-nondesignated classifications. Areas that were formerly "nondesignated" areas are classified "Category I" in these regulations. These areas are allowed a limited increase in SO_2 concentrations over baseline SO_2 concentrations. Areas that were formerly "designated" areas are now classified "Category III." These areas can have the highest allowable SO_2 concentration above which no new source of SO_2 would be permitted. The incremental ambient air standards of SO_2 under these regulations are listed in Table 1.37. The Air Pollution Control Commission may consider redesignation of areas after receiving a request for redesignation and holding at lease one public hearing in the affected area. Requests for redesignation shall, at a minimum, include information as to (1) growth anticipated in the area, (2) the social, environmental, and economic effects of such redesignation upon the area being proposed for redesignation, and (3) any impacts of such proposed redesignation upon regional, state, or national interests. This process provides the mechanism for an area to be designated a Category II area.

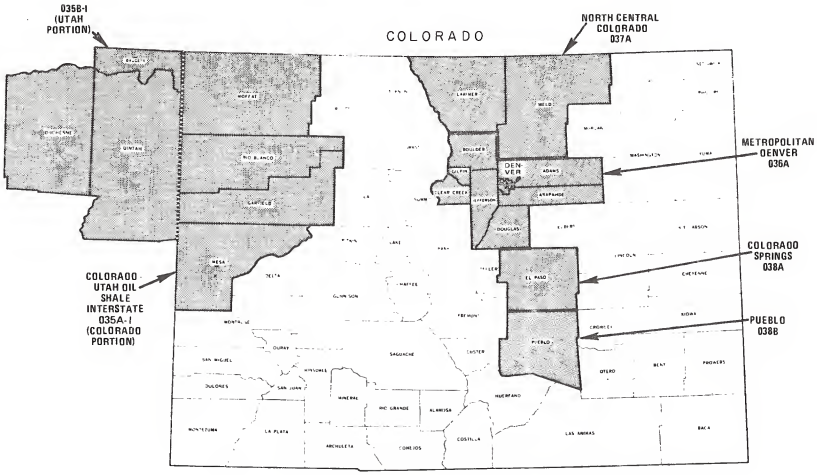

FIGURE 1.10

AIR QUALITY MAINTENANCE AREAS IN COLORADO

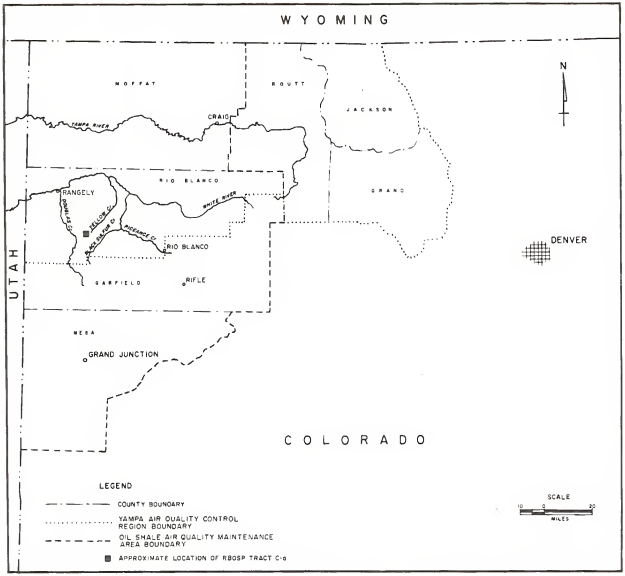

FIGURE 1.11

PART OF THE STATE OF COLORADO SHOWING THE YAMPA INTRASTATE AQCR, THE COLORADO PORTION OF THE COLORADO-UTAH OIL SHALE AIR QUALITY MAINTENANCE AREA (AQMA), AND THE APPROXIMATE LOCATION OF THE RBOSP TRACT C-a

TABLE 1.37

STATE OF COLORADO SULFUR DIOXIDE AMBIENT AIR STANDARDS, 1975

Averaging Intervals	Maximum Allowable SO_2 Increments Over Baseline				Maximum Allowable Concentrations of SO_2	
	Category I (formerly non-designated areas)		Category II		Category III (formerly non-designated areas)	
	$\mu g/m^3$	ppm 1/	$\mu g/m^3$	ppm 1/	$\mu g/m^3$	ppm 1/
Annual Mean	3	0.001	15	0.005	60 2/	0.021
24-hr max	15	0.005	100	0.035	260 2/	0.091
3-hr max	75	0.026	700	0.245	1300 2/	0.455

1/Equivalent values in parts per million at 0 C and 760 mm Hg (Torr).

2/Not to be exceeded more than once in a twelve-month period.

Source: Colorado Air Pollution Control Commission 1975.

Gaseous and particulate concentrations measured at each site were compared with the applicable federal and state ambient air quality standards. A summary of the comparison results for each quarter and for the year is given in Tables 1.38 and 1.39. These tables show the standards, the total number of times each standard was exceeded at all sites during the time period covered by the table, and the maximum concentration measured at each site for the averaging time interval specified by each standard.

Mean concentrations measured for all parameters were low compared to the standards (Tables 1.26 to 1.28). However, particulates, ozone and non-methane hydrocarbons occasionally exceeded the standards. Federal 24-hr maximum primary particulate standards were exceeded once, in the fall, during each year. The federal 24-hr maximum secondary particulate standards were exceeded 12 times during the two base years. This is the only standard that was exceeded more times in the second year than the first. The federal primary and secondary annual standards (geometric mean) were not exceeded for either study year. The range of annual geometric means for particulates was 8 to 18 $\mu g/m^3$, which is 11 to 24 percent of the federal primary annual standard and 12 to 30 percent of the federal secondary annual standard. State 24-hr particulate standards were exceeded six times during the two years; two-thirds of these were in 1975-1976. The state annual standard (arithmetic mean) was not exceeded for the study years. The range of annual arithmetic means was 11 to 24 $\mu g/m^3$ which is 24 to 53 percent of the state standard federal primary and secondary 1-hr maximum ozone standards were exceeded five times during the two-year period. All of these occurrences were during the summer of 1975 and only at Site 3. Non-methane hydrocarbon concentrations exceeded the federal 3-hr maximum (6-9 a.m. only) standard 137 times during the two-year period. Of these exceedences 70 percent (94) were in 1975-1976. There are no identified local sources of non-methane hydrocarbons to account for the high concentrations observed.

TABLE 1.38

COMPARISON OF FEDERAL AND STATE AIR QUALITY STANDARDS TO MEASUREMENTS MADE FOR THE YEAR (FEBRUARY 1975 THROUGH JANUARY 1976), RBOSP

PARAMETER	STANDARDS				TIMES STANDARD EXCEEDED DURING YEAR	MEASURED MAXIMUM Site 1			MEASURED MAXIMUM Site 2			MEASURED MAXIMUM Site 3			MEASURED MAXIMUM Site 4		
	Type of Standard 3/	Time Interval	Concentration µg/m³	Concentration ppm		Concentration µg/m³	Concentration ppm	Time	Concentration µg/m³	Concentration ppm	Time	Concentration µg/m³	Concentration ppm	Time	Concentration µg/m³	Concentration ppm	Time
CO	Primary and Secondary 1/	1-hr max.	40,000	35	0	4824	4.213	0700 7/18	—	—	—	6823	5.959	1100 9/1	—	—	—
CO	Primary and Secondary 1/	8-hr max.	10,000	9	0	4592	4.011	0800 7/18	—	—	—	5660	4.943	1100 9/1	—	—	—
Non-methane Hydrocarbon	Primary and Secondary 1/	3-hr max. (6-9 am only)	160	0.24	94	388	0.594	9/20	371	0.567	9/2	166	0.254	8/7	505	0.772	6/9
NO_2	Primary and Secondary 1/	Annual Arith. Mean	100	0.05	0	2	0.001	2/1/75-1/31/76	—	—	—	4	0.002	2/1/75-1/31/76	—	—	—
Ozone	Primary and Secondary 1/	1-hr max.	160	0.08	5	135	0.068	1200 7/4	—	—	—	177	0.089	1900 8/29	—	—	—
SO_2	Primary 1/	24-hr max.	365	0.14	0	37	0.014	1700 7/31	24	0.009	1700 10/17	19	0.007	1300 11/1	82	0.031	1800 10/28
SO_2	Primary 1/	Annual Arith. Mean	80	0.03	0	8	0.003	2/1/75-1/31/76	5	0.002	2/1/75-1/31/76	3	0.001	2/1/75-1/31/76	19	0.007	2/1/75-1/31/76
SO_2	Secondary 1/	3-hr max.	1300	0.5	0	114	0.043	1600 7/31	178	0.067	2000 10/16	50	0.019	0700 7/30	345	0.130	2200 10/22
Particulates	Primary 1/	24-hr max	260	NA	1	212	NA	7/3	102	NA	10/7	247	NA	8/17	469	NA	10/7
Particulates	Primary 1/	Annual Geo. Mean	75	NA	0	9	NA	2/1/75-1/31/76	9	NA	2/1/75-1/31/76	18	NA	2/1/75-1/31/76	13	NA	2/1/75-1/31/76
Particulates	Secondary 1/	24-hr max.	150	NA	5	212	NA	7/3	102	NA	10/7	247	NA	8/17	469	NA	10/7
Particulates	Secondary 1/	Annual Geo. Mean	60	NA	0	9	NA	2/1/75-1/31/76	9	NA	2/1/75-1/31/76	18	NA	2/1/75-1/31/76	13	NA	2/1/75-1/31/76
Particulates	State 2/	24-hr max.	150 4/	NA	4	162	NA	7/3	78	NA	10/7	189	NA	8/17	360	NA	10/7
Particulates	State 2/	Annual Arith. Mean	45 4/	NA	0	16	NA	2/1/75-1/31/76	14	NA	2/1/75-1/31/76	24	NA	2/1/75-1/31/76	22	NA	2/1/75-1/31/76

1/Environmental Protection Agency Regulations on National Primary and Secondary Ambient Air Quality Standards (40 CFR 50; 36 FR 22384, November 25, 1971: as amended by 38 FR 25678, September 14, 1973; 40 FR 7042, February 18, 1975).
2/Ambient air standards for metropolitan Denver air quality control region, air quality control areas, and the State of Colorado; Adopted: September 10, 1970, Effective: December 17, 1970.
3/All EPA standards are at reference conditions of 25°C and 760 mm Hg.
4/Measured at ambient temperature and pressure.
NA = Not Applicable.
— = Not measured at this site.

TABLE 1.39

COMPARISON OF FEDERAL AND STATE AIR QUALITY STANDARDS TO MEASUREMENTS MADE FOR THE YEAR (FEBRUARY 1976 THROUGH JANUARY 1977), RBOSP

Parameter	Standards				Times Standard Exceeded During Year	Measured Maximum Site 1			Measured Maximum Site 2			Measured Maximum Site 3			Measured Maximum Site 4		
	Type of Standard 3/	Time Interval	Concentration µg/m³	Concentration ppm		Concentration µg/m³	Concentration ppm	Time	Concentration µg/m³	Concentration ppm	Time	Concentration µg/m³	Concentration ppm	Time	Concentration µg/m³	Concentration ppm	Time
CO	Primary and Secondary 1/	1-hr max.	40,000	35	0	1780	1.555	0200 3/16	----	----	----	2087	1.826	1400 2/04	----	----	----
CO	Primary and Secondary 1/	8-hr max.	10,000	9	0	1760	1.537	0300 3/16	----	----	----	1864	1.631	2100 2/04	----	----	----
Non-methane Hydrocarbon	Primary and Secondary 1/	3-hr max. (6-9 am only)	160	0.24	43	335	0.513	10/20	228	0.348	3/04	86	0.132	12/05	190	0.291	1/30
NO_2	Primary and Secondary 1/	Annual Arith. Mean	100	0.05	0	0	0.000	2/1/76-1/31/77	----	----	----	0	0.000	2/1/76-1/31/77	----	----	----
Ozone	Primary and Secondary 1/	1-hr max.	160	0.08	0	117	0.060	1800 4/09	----	----	----	133	0.068	1400 7/03	----	----	----
SO_2	Primary 1/	24-hr max.	365	0.14	0	18	0.007	0000 6/23	55	0.021	1200 5/21	23	0.009	1800 4/26	133	0.051	0500 9/29
SO_2	Primary 1/	Annual Arith. Mean	80	0.03	0	3	0.001	2/1/76-1/31/77	3	0.001	2/1/76-1/31/77	7	0.003	2/1/76-1/31/77	15	0.006	2/1/76-1/31/77
SO_2	Secondary 1/	3-hr max.	1300	0.5	0	94	0.036	0000 7/01	444	0.170	1500 5/20	58	0.022	1900 7/16	253	0.097	1600 5/08
Particulates	Primary 1/	24-hr max.	260	NA	1	81	NA	7/21	57	NA	8/26	281	NA	11/03	182	NA	11/03
Particulates	Primary 1/	Annual Geo. Mean	75	NA	0	8	NA	2/1/76-1/31/77	8	NA	2/1/76-1/31/77	12	NA	2/1/76-1/31/77	12	NA	2/1/76-1/31/77
Particulates	Secondary 1/	24-hr max.	150	NA	7	81	NA	7/21	57	NA	8/26	281	NA	11/03	182	NA	11/03
Particulates	Secondary 1/	Annual Geo. Mean	60	NA	0	8	NA	2/1/76-1/31/77	8	NA	2/1/76-1/31/77	12	NA	2/1/76-1/31/77	12	NA	2/1/76-1/31/77
Particulates	State 2/	24-hr max.	150 4/	NA	2	62	NA	7/21	44	NA	8/26	215	NA	11/03	139	NA	11/03
Particulates	State 2/	Annual Arith. Mean	45 4/	NA	0	11	NA	2/1/76 1/31/77	12	NA	2/1/76 1/31/77	20	NA	2/1/76 1/31/77	19	NA	2/1/76-1/31/77

1/Environmental Protection Agency Regulations on National Primary and Secondary Ambient Air Quality Standards (40 CFR 50; 36 FR 22384, November 25, 1971: as amended by 38 FR 25678, September 14, 1973; 40 FR 7042, February 18, 1975).
2/Ambient air standards for metropolitan Denver air quality control region, air quality control areas, and the State of Colorado; Adopted: September 10, 1970, Effective: December 17, 1970.
3/All EPA standards are at reference conditions of 25 C and 760 mm Hg.
4/Measured at ambient temperature and pressure
NA = Not Applicable
-- = Not measured at this site.

In addition to the standards shown in Tables 1.38 and 1.39, there is a State of Colorado SO_2 ambient air standard (Colorado Air Pollution Control Commission, 1975). This SO_2 standard became effective in December 1975. It established maximum allowable increases in ambient SO_2 concentrations over existing background levels. The background levels are to be determined by measurement or estimation. The present baseline monitoring program will, therefore, help define the background level of the area. The background levels of SO_2 measured on Tract C-a for both baseline years are shown in Table 1.40.

TABLE 1.40

SO_2 BACKGROUND CONCENTRATIONS FOR ALL SITES FOR TRACT C-a, RBOSP

Time Interval	Concentration			
	($\mu g/m^3$)		(ppm)	
	1975-1976	1976-1977	1975-1976	1976-1977
Annual Mean	11	7	0.004	0.004
24-hr Maximum	82	57	0.031	0.022
3-hr Minimum	345	212	0.130	0.081

IV. REPRESENTATIVENESS OF TRACT DATA

Air quality data from areas adjacent to Tract C-a is sparse. The tract data show occasional violations of air quality standards for total suspended particulates (TSP) as do similar monitoring stations in Craig, Rifle, and Grand Junction. Data from Tract C-b obtained in 1975 show that the annual geometric mean concentrations (9.5 $\mu g/m^3$) are nearly the same (9 $\mu g/m^3$) as that measured at Sites 1 and 2 on Tract C-a. The annual average TSP concentration measured at Sites 3 and 4 on Tract C-a were higher than at Sites 1 and 2 because the monitors at both sites were located adjacent to unpaved public roads. All of the violations of TSP standards measured

on Tract C-a were observed on weekends, holidays or during hunting season. TSP standards are not exceeded on Tracts C-b or U-a, U-b during their first baseline year. The oxidant levels (as ozone) measured on Tract C-a show occasional violations of the air quality standard. Similar concentration levels were observed on Tracts U-a, U-b and in 1975 the maximum hourly average ozone concentration measured on Tract C-b was at the air quality standard limit. The similarity of results obtained by measurements taken in the three tract areas lends credence to the representativeness of the Tract C-a data. The oxident is not the result of typical smog producing chemical reactions because some of the regional chemical components are not present. The elevation of the tract areas, the strong insolation, and the lack of scattering and absorbing material in the atmosphere enhances the formation of ozone from the reaction of solar radiation on atmospheric oxygen. Diurnal cycles in the ozone concentration were noted on Tract U-a, U-b as well as the two Tract C-a monitoring sites.

The non-methane hydrocarbon concentrations measured on Tract C-a exceeded air quality standard limits on a number of occasions throughout the baseline data period. Similar violations were measured on Tract C-b, and U-a, U-b. The only apparent source of these hydrocarbons seems to be natural. Vegetation has been suspected as well as volatilization of compounds from surface shale. The similarity among the various tract measurements supports the representativeness of the Tract C-a data.

The ambient air concentration of the other pollutants measured on Tract C-a (NO, NO_x, SO_2, H_2S, and CO) all average near or below the reliable threshold of detection of the measuring instrumentation, and exhibit maximum hourly values which are in general at least one order of magnitude below applicable air quality standards.

The general character of the baseline data set, and the comparability of average and maximum values with similar data from the other tract monitoring efforts support the conclusion that the baseline data set does represent the air quality existing in the Tract C-a area.

V. RELIABILITY OF BASELINE DATA

Reliability of baseline air quality data were ensured by a comprehensive quality assurance program. Maintenance, operational, calibration, handling, shipping, storage, and inspection procedures were documented. Calibration procedures were traceable to established standards. Calibration schedules were established and rigorously executed. Quality assurance audits were scheduled on a regular basis to monitor compliance with calibration and equipment maintenance procedures and other elements of the program. Discrepencies were documented and resolved. Any deviations are documented and affected data were verified before being incorporated into the data base. The documentation system is program-wide and is continuously up-dated.

The objectives of the air quality portion of the climatology and air quality baseline program are presented in Section I of this chapter. The quantity criterion may be evaluated by a comparison of the 90 percent goal with the values in Table 1.41. The explanation of how these percentages were obtained is presented in Section I of Chapter 2.

These annual meteorological percentages, in combination with the stringent quality assurance program, satisfy the quality and quantity requirements of the Oil Shale Leave Environmental Stipulations.

VI. RELATIONSHIPS BETWEEN AIR QUALITY AND METEOROLOGICAL CONDITIONS

Manual calculations of important relationships between air quality and meteorological parameters were performed for the second year of baseline data in order to verify that similar relationships occurred during the second year. These calculations indicated that the presentations in the first annual report (RBOSP DDP 1976) remain valid for the second year.

Precipitation and the mean THC and CH_4 levels are the primary exceptions to the above statement. The levels of THC and CH_4 have been discussed previously as possibly being related to vegetation cover (Reference section II of this chapter, and the DDP). The values showing this increase in mean THC and CH_4 annual values for the respective years were illustrated in section II of this chapter.

TABLE 1.41

BIENNIAL AIR QUALITY CUMULATIVE PERCENTAGE RECOVERED[1/]
(1 FEBRUARY 1975 THROUGH 31 JANUARY 1977), RBOSP

Parameter	Annual Percentage of Recovery[2/]	
	1975-1976	1976-1977
High Volume Sampler (HVS)	93.5	99.1
Sulfur Dioxide (SO_2)	94.7	94.7
Hydrogen Sulfide (H_2S)	90.5	94.7
Total Hydrocarbons (THC)	95.8	92.9
Methane (CH_4)	95.7	91.8
Carbon Monoxide	95.0	94.9
Ozone (O_3)	98.0	97.1
Nitric Oxide (NO)	96.7	94.4
Oxides of Nitrogen (NO_x)	96.7	94.4

1/If the total instrument operational hours are used for the numerator in the equation for "Monthly Percentage Recovered," the percentages reported would be higher than those indicated.

2/Annual goal: $\geq$90 percent.

CHAPTER 5 - ATMOSPHERIC DIFFUSION

I. STABILITY INDEX

Emissions of gaseous pollutants are dispersed and diluted by the atmosphere. High wind speeds can cause dilution of the emissions even near the source. Gross wind direction changes disperse the emissions over a greater area where they can be diluted by other mechanisms. Wind turbulence and buoyancy enhance the rate at which the emissions are diluted by the atmosphere and thereby reduce ambient pollutant concentrations. Wind speed and wind direction have been discussed previously. The mechanisms of turbulence and buoyancy and their indicators are discussed below.

Turbulence is generated by wind shear in the gradient wind, by surface structures or rough topography, and by atmospheric instability. Turbulence is readily measured by the spectra (frequency and magnitude) of wind direction changes. Although turbulence is three-dimensional, the greater changes are in the horizontal wind direction fluctuations. Horizontal wind direction fluctuations are measured at Tract C-a using the 10-m level Site 1 wind direction sensor. The spectra of fluctuations are generally random (Gaussian) and the measurement is the standard deviation expressed as wind sigma as calculated by the on-site minicomputer.

Wind sigma was measured at Site 1 at the 10-m level from June 1975 through January 1977. The minimum, maximum, and mean wind sigma are presented for both baseline years in Chapter 2. In general, wind sigmas are greater during the mid-day hours, from about three hours after sunrise to about three hours before sunset.

The gravitational pull of the earth on the air results in an atmospheric pressure decrease with altitude. In the absence of any selected heating or cooling of the atmosphere, atmospheric temperature will decrease (lapse)

with increasing altitude at a magnitude termed the adiabatic lapse rate. The dry adiabatic lapse rate (absence of water vapor) is 0.98 C per 100 m. As a result of intense heating (insolation) of the earth's surface by the sun, the actual lapse rate within the first hundred meters of the surface may exceed the dry adiabatic lapse rate and the air becomes buoyant. This means that a parcel of air disturbed upward and expanding adiabatically to the lower pressure is lighter than the surrounding air and tends to continue its rise. The magnitude of this buoyancy can be observed in the rapid vertical growth of cumulus clouds during summer days. Such an atmosphere is said to be unstable. On the contrary, during clear nights, the surface may radiate heat to space and create a lapse rate that is less than the adiabatic lapse rate and may even result in a temperature that increases with height (an inversion). In this case, the disturbed air parcel is heavier than the surrounding air and returns toward the surface. This atmosphere is said to be stable. Substances emitted into an unstable atmosphere tend to rise and disperse. Emissions released into a stable atmosphere tend to move downwind with little vertical dispersion.

At Site 1, the difference between air temperature at the 10-m and at the 60-m levels was measured. This difference is called delta temperature (temperature difference or ΔT). The sign of delta temperature is the same as lapse rate (decreasing temperature with height is positive delta temperature). Because the height difference is 50 m, the lapse rate (C/100 M) is twice the delta temperature (C/50 m) value and the dry adiabatic lapse rate corresponds to a delta temperature of 0.49 C.

In general, the delta temperature data indicate stability at night and instability during the middle of the day. The minimum delta temperatures (most stable conditions) were greater than the maximum delta temperatures (most unstable conditions). The breakup of the usual surface inversion generally occurred within an hour after sunrise. In general, the mean nocturnal inversion during winter and fall was significantly more intense than that during spring and summer.

In analyzing the diffusion characteristics of the atmosphere with meteorological data, Pasquill (Slade 1968) discovered that categorization of effluent dispersion resulted in lapse rate also being grouped into well-defined classes. These relationships are illustrated in Table 1.42.

Mean delta temperature values were categorized according to stability classifications, grouped by season and annually, and converted to percentage of occurrence; the results for February 1975 through January 1976 and February 1976 through January 1977 are presented in Tables 1.43 and 1.44. Also included in the tables are the average associated wind speeds. For both years the highest wind speeds were associated with the more unstable categories rather than the neutral stability category. The high wind speeds which were found to be associated with the extremely stable category G during the summers of 1975 and 1976 were examined and it was found that these winds almost always came from the southwest through northwest quadrant. These winds have been associated with the movement of fronts through the area generally during the hours of darkness.

After the experience gained from the two years of baseline data and the Tracer Studies, the urban X/Q values that were to be inserted in this section have been deleted. This deletion has been made due to misleading conclusions that might be drawn from these values.

II. TRACER MEASUREMENTS

A tracer study was conducted at Tract C-a of the Rio Blanco Oil Shale Project during 17 to 28 October 1976. Ten specific test runs varying in length from 4 to 24 hours were made which resulted in 87 hours of dispersion information. The EPA Valley Model was used to predict concentrations under similar meteorological conditions. Details of this report are available in the RBOSP Tracer Report, 1 April 1977. The tracer study data are currently undergoing further analysis.

TABLE 1.42

CLASSIFICATION OF ATMOSPHERIC STABILITY

Stability Classification	Pasquill Category	Temperature gradient with height (C/100m) (Negative lapse rate)	Delta Temperature (ΔT) (C/50m)
Extremely unstable	A	less than -1.9	greater than 0.95
Moderately unstable	B	-1.9 to -1.7	0.95 to 0.85
Slightly unstable	C	-1.7 to -1.5	0.85 to 0.75
Neutral	D	-1.5 to -0.5	0.75 to 0.25
Slightly stable	E	-0.5 to 1.5	0.25 to -0.75
Moderately stable	F	1.5 to 4.0	-0.75 to -2.00
Extremely stable	G	greater than 4.0	less than -2.00

Source: Slade, 1968; NRC, 1972

TABLE 1.43

PERCENTAGE OF OCCURRENCE OF STABILITY CLASSES AND ASSOCIATED WIND SPEEDS USING DELTA TEMPERATURE FOR FEBRUARY 1975 THROUGH JANUARY 1976, RBOSP

Period	Percentage of Occurrence of Stability Class							
	A	B	C	D	E	F	G	Total %
Winter 1975 (February)	2.74	4.18	6.92	32.42	48.85	4.76	0.14	100
Spring 1975 (March, April, May)	11.54	6.19	6.05	30.27	40.26	5.58	0.09	100
Summer 1975 (June, July, August)	18.38	6.72	6.11	18.19	35.54	13.20	1.87	100
Fall 1975 (September, October, November)	5.36	4.09	5.27	28.43	43.96	11.67	1.23	100
Winter 1975-1976 (December, January)	0.21	0.34	1.03	33.52	54.42	10.08	0.41	100
Annual (February 1975 through January 1976)	9.07	4.64	5.07	27.56	43.05	9.73	0.87	100
	Associated Wind Speeds (mph)							Total Weighted Average
Winter 1975 (February)	7.16	6.95	7.68	9.58	6.19	6.09	4.11	7.53
Spring 1975 (March, April, May)	9.87	9.28	9.61	9.55	7.39	7.58	5.08	8.59
Summer 1975 (June, July, August)	10.26	8.98	8.05	7.84	5.60	7.59	9.09	7.57
Fall 1975 (September, October, November)	12.56	10.84	9.29	8.82	6.37	6.77	7.77	7.80
Winter 1975-1976 (December, January)	9.23	9.68	8.09	8.80	5.12	3.94	3.57	6.28
Annual (February 1975 through January 1976)	10.41	9.38	8.80	8.94	6.16	6.63	7.71	7.65

TABLE 1.44

PERCENTAGE OF OCCURRENCE OF STABILITY CLASSES AND ASSOCIATED WIND SPEEDS USING DELTA TEMPERATURE FOR FEBRUARY 1976 THROUGH JANUARY 1977, RBOSP

Period	Percentage of Occurrence of Stability Class							
	A	B	C	D	E	F	G	Total %
Winter 1976 (February)	0.15	1.84	1.99	43.33	44.42	7.14	1.13	100
Spring 1976 (March, April, May)	7.27	4.14	5.35	35.21	39.35	8.29	0.39	100
Summer 1976 (June, July, August)	13.28	5.97	6.97	23.80	34.33	14.27	1.38	100
Fall 1976 (September, October, November)	4.25	4.40	6.52	27.73	46.86	10.00	0.24	100
Winter 1976-1977 (December, January)	0.62	0.83	2.41	29.68	51.10	14.53	0.83	100
Annual (February 1976 through January 1977)	6.31	3.92	5.28	30.24	42.36	11.16	0.73	100
	Associated Wind Speeds (mph)							Total Weighted Average
Winter 1976 (February)	19.82	7.52	7.43	10.90	6.50	5.11	1.32	8.31
Spring 1976 (March, April, May)	11.95	11.70	10.01	8.46	6.24	6.74	8.12	7.91
Summer 1976 (June, July, August)	11.64	10.92	9.65	8.11	5.59	7.18	8.25	7.86
Fall 1976 (September, October, November)	10.74	9.76	8.95	7.19	5.04	6.49	6.59	6.49
Winter 1976-1977 (December, January)	9.00	10.04	9.83	6.83	4.45	4.96	4.14	5.43
Annual (February 1976 through January 1977)	11.73	10.40	9.41	7.99	5.50	6.36	6.54	8.28

The preliminary results indicate:

- Under stable atmospheric conditions (Stability Class E) and relatively high wind speeds, no concentrations were usually predicted east of the release tower. It appears that mechanical turbulence induced by local terrain features was actually greater than would be expected under these conditions and that neutral atmospheric conditions probably prevailed. A comparison of the measured concentrations to predicted concentrations assuming neutral conditions showed similar values during some of these time periods.
- No consistent trend was found when comparing measured to predicted concentrations for stable atmospheric conditions and easterly winds; that is, in the high terrain area west of the release tower.
- For neutral atmospheric conditions (Stability Class D), predicted to measured ratios ranged from 0.5 to 6.0. In general, the Valley Model overpredicted by a larger margin than when it underpredicted.
- For unstable atmospheric conditions (Stability Classes A, B, and C), the measured values were both higher and lower than predicted concentrations. Factors such as distance from release tower, terrain height, and lack of wind persistence in both speed and direction contributed to making comparisons between measured and predicted concentrations difficult.

In order to account more accurately for terrain effects and site specific meteorological factors, RBOSP has had an air quality dispersion model (AQPUF) tailored to the Tract C-a site. This model allows a more accurate prediction of short term (1 to 24 hour) concentration levels than the Valley model which was developed originally to predict long term (3 months to annual) average concentrations in valley terrain. The tracer test results will be reinterpreted with the AQPUF model.

CHAPTER 6 - VISIBILITY

I. TRACT C-a VISIBILITY

Observations of visibility using the visual method were performed every third day during the baseline study. Minimum visibility for 50 percent of the observations exceeded 100 miles for the first baseline year and 80 miles for the second baseline year (Figure 1.12).

The general, slight, decrease in minimum visibility in the second baseline year appears to have been associated with more occurrences of low cloud formations and haze conditions during the Summer and Fall Quarters. Occurrences of minimum visibility observations less than 80 miles indicate good similarity for the two baseline years.

Visibility in the Piceance Creek basin is exceptionally good and is primarily reduced by low cloud formations, sometimes occurring with precipitation, or light haze.

II. BASIN WIDE VISIBILITY

A second visibility program was conducted for the purpose of quantifying visibility measurements using photographic densitometers to measure the visual range on photographic exposures of identified geographical locations at a number of known ranges from the camera. This program was designed to establish criteria for both Tract C-a and C-b.

Measurements were made every sixth day. During the year a total of 1,548 usable measurements were acquired. Daily mean visual ranges varied widely and directional differences were detected in each season. The photographic technique provides certain advantages over the individual observer: (1) a photograph is a permanent record, (2) relative light intensities can be measured accurately, (3) film may be calibrated for sensitivity, (4) a camera does not suffer from eye fatigue or change in focus, and (5) a telephoto lense on the camera will permit measurements over long atmospheric path lengths.

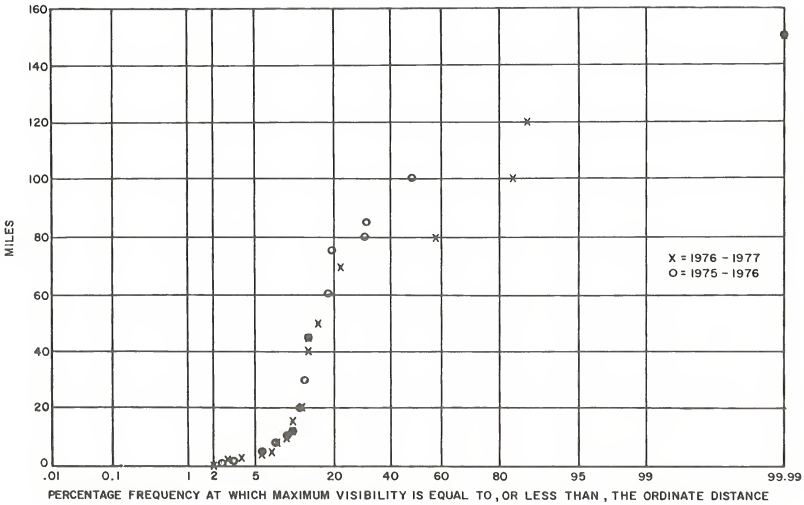

FIGURE 1.12

CUMULATIVE FREQUENCY DISTRIBUTION OF VISIBILITY FOR FEBRUARY 1975 THROUGH JANUARY 1976 AND FEBRUARY 1976 THROUGH JANUARY 1977, RBOSP

All of the study photographs were taken from the same location. The site was located on a ridge approximately 8 miles southwest of Piceance Creek between Hunter Creek and Dry Gulch. From this point four views were selcted from one to the north-northwest clockwise to the east-northeast. At least two objects in each view were used to provide data for the calculation of the visual range. A total of nine points in the four views were used as known references. A 35mm camera equipped with an 800mm telephoto lense was used to take the pictures at prescribed hours each sixth day. Conventional color slides were also made in order to record sky and weather conditions during the data gathering periods. Photographs were taken at 0830, 0930, 1030, 1130, 1300, 1400, and 1500 hours MST.

The film used for photographing objects for visual range determinations (black and white) was calibrated prior to development by exposure to eleven calibrated light intensities. The film development was closely controlled and the final calibration performed with a precision densitometer.

The study resulted in a volume of data on visual ranges. Daily mean visual ranges were computed from the average of 28 measurements taken from the four views over the seven-hour period. Daily mean visual range was greater than 42 miles 95 percent of the time, often greater than 100 miles, and half the time exceeded 76 miles. The maximum mean daily visual range measured during the year was 130 miles., the minimum was 32 miles. Figure 1.13 shows the measured daily mean visual range for the four views during each season of the measurement year. The general correlation between visual range and view indicates that the atmospheric influence on visibility was widespread and generally uniform in the air mass between the sampling site and the target objects in the photographs.

Minor restrictions to visibility, such as haze or smoke, were often observed. Early morning haze was often dispelled by increasing winds in the late morning or early afternoon.

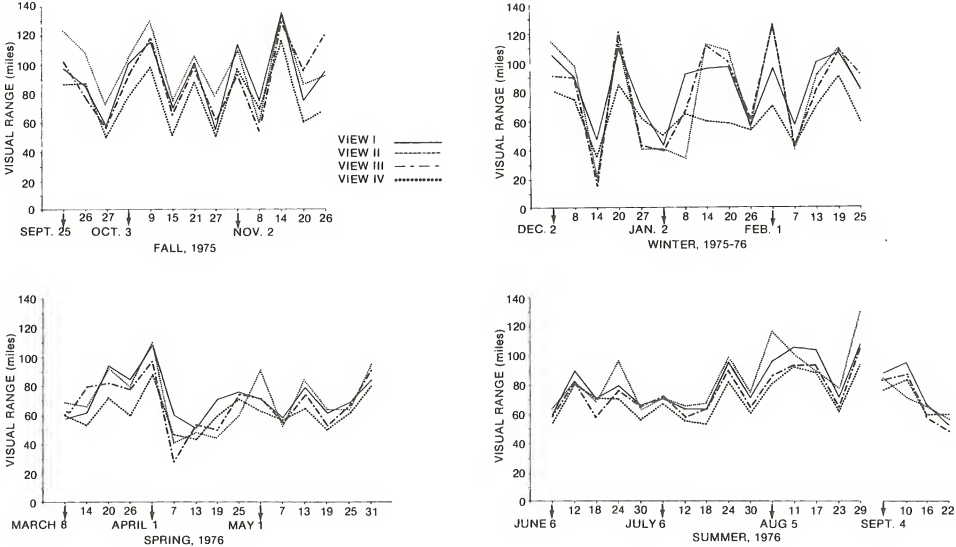

FIGURE 1.13
VARIATION IN DAILY MEAN VISUAL RANGE FOR EACH VIEW
PICEANCE CREEK BASIN, COLORADO
SEPTEMBER, 1975 - SEPTEMBER 1976

Monthly mean visual range was calculated for each month of the study. The monthly means varied widely and had a standard deviation of from 14.8 to 31.1 miles. One overlap month (September 1975 and September 1976) had a mean visual range of 77 miles in 1975 and 74 miles in 1976. The lowest mean visual range occurs during the spring season, the greatest during the fall. Summer and winter seasons during the study exhibited similar ranges. When mean visual range is reduced in one direction, it is reduced in all directions.

The largest variation in overall mean visibility occurred along the path which lies across the Piceance Creek basin. The mean visual range along this path was lowest during each season. The speculation is that atmospheric suspended particulates become trapped in the basin and are not released until the basin air movement is sufficient to clear away the trapped material.

The present visibility in the site region is excellent. Concurrent measurements of suspended particulate and air pollutants indicate very low ambient air concentrations. Visibility is a qualitative measure of regional visual ranges against which future comparisons may be made.

CHAPTER 7 - NOISE

The initial study was performed during the period August through December 1975. The data and results have been reported previously (RBOSP DDP, 1976).

In brief, the data summary does not indicate significant intersite or specific octave band trends (Table 1.45). Baseline A-Scale maximum noise level data are considerably less the the regulation for construction levels in existence at the time of the study (Table 1.46).

During the summer of the second baseline data year, a second, intensive 3-day noise survey was conducted at each of the four monitoring sites on the tract. Sound levels were measured and recorded in 20-minute segments during five divisions of the day:

- Morning (0700-1200).
- Afternoon (1200-1800).
- Evening (1800-2200).
- Nighttime (2200-0700).

The tape recordings were analyzed at a later date. Data were not used if the wind speed was greater than 6 m/sec, and wind pops and aircraft over-flight were edited from the tape. Data were not recorded when the wind speed or relative humidity was high (over 90 percent R.H.) at the beginning of a 20-minute period.

The octave band centers ranged from 31.5Hz to 16KHz. Computations were made to determine the cumulative frequency of occurrence of specific noise levels, the noise level exceeded 95 percent of the time, the noise level exceeded 5 percent of the time, the integrated 24-hour average, the constant noise equivalent of the integrated noise recording, and the A-weighted noise intensity. The A-weighted measurement represents what would be perceived by the human ears as opposed to the absolute pressure of the sound waves represented by the other measures.

TABLE 1.45

NOISE LEVELS MEASURED AT SITES 1, 2, 3, AND 4, AUGUST 1975 THROUGH DECEMBER 1975, RBOSP

Day No.	Octave Band Center Frequency (Hz)	NOISE LEVEL (dB)[2/]											
		SITE 1			SITE 2			SITE 3			SITE 4		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1	A[1/]	50	55	52	43	52	46	44	52	50	50	53	51
2	31.5	52	58	55	56	70	58	53	59	56	53	60	57
3	63	57	62	59	55	62	56	55	58	56	57	60	58
4	125	53	57	56	49	60	52	54	63	56	54	55	55
5	250	49	58	54	45	52	48	50	56	51	45	45	45
6	500	40	44	42	35	38	37	34	45	40	48	53	50
7	1000	47	53	50	34	45	40	36	46	42	45	52	47
8	2000	49	55	51	45	55	48	46	53	51	46	52	51
9	4000	NA	NA	NA	47	55	52	47	54	49	67	77	74
10	8000	NA	NA	NA	43	52	50	44	51	48	70	78	72
11	16000	27	30	32	NA	NA	NA	28	48	35	28	38	34

1/ A Weighting - Units in dBA

2/ Ref. level 20 $\mu N/m^2$

NA - Data not available

TABLE 1.46

PERMISSIBLE NOISE EXPOSURES[1/]
AS OF DECEMBER 1975, RBOSP

Sound Level (dBA)[2/] (Slow Response)	Duration Hr/Day
90	8
92	6
95	4
97	3
100	2
102	1-1/2
105	1
110	1/2
115	1/4 or less
Exposure to impulsive or impact noise exceeding 140-dBA peak sound pressure level is to be avoided.	

[1/] From Table D-2, Subpart D, Section 1926.52, Safety and Health Regulations for Construction, Department of Labor Standards, Volume 36, Number 75, Saturday April 17, 1971, Washington D.C., Part II, Federal Register.

From Table G-16, Williams-Steiger Occupational Safety and Health Act, Subpart A, Section 1910.95, Department of Labor, Volume 37, Number 202, Wednesday, October 18, 1972, Washington, D.C., Part II, Federal Register.

From Table I of Walsh-Healey Public Contracts Act, Title 41, Part 50-204, Volume 34, Number 96, Tuesday, May 20, 1969, Washington, D.C., Federal Register.

[2/] Measured on the A-Scale of a Standard Sound Meter at Slow Response.

Table 1.47 presents a summary of ambient sound data obtained during a 24-hour period on Rio Blanco Tract C-a. The sound levels are given in decibel units. The first column appearing under each site location shows the ambient sound level which is exceeded 95 percent of the time (L_{95}). The second column (Leq) is the constant noise level which equals the integrated fluctuating noise level actually measured. The third column (L_5) is the noise level exceeded 5 percent of the time. At the bottom of the table is a line of data giving the A-weighted noise values which are the noise intensities that would be perceived by the human ear. The last line of data is the day/night equivalent sound level. This number is used by the Federal EPA to evaluate ambient noise for various land use categories. Standards for various land use categories have been established to control degradation in order to protect human health and welfare.

The two sound surveys are not directly comparable in the strictest sense. The first one (Table 1.45) includes wind noise and some bias due to the recorder location in relation to the air quality monitoring trailer. The trailers are equipped with full time air conditioning and have continuous noise levels from sampling pumps. During the second survey (Table 1.47) extensive efforts were made to eliminate strictly local (man-induced) noise sources from baseline data. Therefore, the second survey is believed to be a much more representative measure of the noise levels throughout the tract area than the first survey.

The results of the two sound level surveys are compared in Table 1.48. The detailed data which support Table 1.47 were examined to determine the minimum level measured during two days of sampling, the maximum level measured during the sampling period, and the 50th percentile of the entire period. These values are comparable to the data from Table 1.45 with respect to means and extremes, but not with respect to total sampling time and editing procedures. The sound levels presented in Table 1.45 (1975) include values obtained under a wide variety of sampling conditions, including periods of windspeed greater than 6 m/sec which have been edited out of the data set presented in Table 1.47 (1976).

TABLE 1.47

SUMMARY OF AMBIENT SOUND DATA OF 24 HOUR PERIOD.
RIO BLANCO TRACT C-a - AUGUST 24 THROUGH AUGUST 26, 1976

24-hour Integrated Average

Octave Band Center Freq. Hz	Site 1 L_{95}	Site 1 L_{eq}	Site 1 L_5	Site 2 L_{95}	Site 2 L_{eq}	Site 2 L_5	Site 3 L_{95}	Site 3 L_{eq}	Site 3 L_5	Site 4 L_{95}	Site 4 L_{eq}	Site 4 L_5
31.5	47.3	64	70.3	53.9	68.1	73.3	37	56.3	62.9	36.4	47.9	55.1
63	46.2	52.7	57.6	46.4	55.7	61.2	42.8	47	50.7	41.1	41.8	44.6
125	32.8	43.5	48.6	34.1	45.6	50.9	32.1	41.6	46.3	29.7	35.6	40.9
250	33.2	37.1	40.8	33.7	37.8	42.6	30.2	37	41.8	26.1	30.6	36.4
500	32.6	34.9	33.6	31.7	32.3	33.7	29.1	31.6	32.6	24	25.7	29.7
1000	32.2	32.8	32.2	31.7	31.7	31.7	29.1	30.1	29.3	24	24.2	24.8
2000	32.2	32.9	32.3	31.7	31.7	31.7	29.1	29.5	29.1	24	24	24
4000	32.2	32.6	33.1	31.7	31.8	31.8	29.1	29.3	29.1	24	24	24
8000	32.2	33	34.7	31.7	31.8	31.9	29.1	29.2	29.1	24	24	24
16000	32.2	32.3	32.5	31.7	31.7	31.9	29.1	29.1	29.1	24	24.2	24
A-wt	31.3	37.8	40.1	31.8	36.9	41.1	29	34.5	39.5	25.9	29.1	33.2
L_{dn}		42			45			36.7			34.1	

TABLE 1.48

COMPARISON OF AMBIENT SOUND LEVEL SURVEY DATA

Year	Noise Level (dB)											
	Site 1			Site 2			Site 3			Site 4		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1975	50	52	55	43	46	52	44	50	52	50	51	53
1976	24	35	64	25	38	66	26	32	65	24	30	72

CHAPTER 8 - CLIMATE AND AIR QUALITY OF THE AREA

The pertinent conclusions based upon the two-year baseline study are:

- A sound, comprehensive data base has been established for the meteorological and air quality parameters measured.
- The data are representative of the tract area, and are similar to the data obtained from the other tracts.
- The air quality is exceptionally good with respect to normal urban area pollutants. Significant pollutant levels are noted occasionally for non-methane hydrocarbons, ozone and suspended particulates. The hydrocarbon and ozone appear to be produced by natural causes.
- The baseline data years may be anomalous with respect to total precipitation, an effect noted over a wide geographic area.
- The visual range from the tract is exceptional, often being in excess of 100 miles.
- The atmospheric stablitiy is similar to arid-desert like regions, and the mixed terrain promotes the dispersion and diffusion of substances released into the atmosphere.

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SECTION 2

AQUATIC RESOURCES

SECTION II - WATER RESOURCES AND AQUATIC BIOLOGY

PREFACE

Successful development of oil shale resources on Tract C-a requires availability of extensive water resource data for the area to aid in development of mining plans; to assess impacts of dewatering, and to plan effective mitigation procedures. The basic objective of the RBOSP water resource baseline program was to provide these data. To this end, baseline studies were conducted to:

- Locate and characterize surface water resources in the area.
- Locate and characterize the groundwater resources within the study area.
- Study aquatic habitats and inventory aquatic biota characteristic of the area.

Several different programs were established, including hydrologic studies of precipitation, spring and seeps, other surface water resources, alluvial aquifers, deep bedrock aquifers, and biological studies of aquatic habitats. Data by several contractors were compiled, and submitted periodically to the AOSS. The collection procedures employed were designed for compliance with RBOSP needs, the Oil Shale Lease Environmental Stipulation, Federal Register, Volume 39, Number 230, Part 3, the Tract C-a Exploratory Plan of May 1974, and subsequent conditions of approval from AOSS.

Data collected during these programs have been used to provide the baseline description and interpretations of Tract C-a hydrology and aquatic biology In addition, these data have been used to develop dewatering schemes for modular and commercial operations, plan flood protection measures, identify the quality, quantity and availability of water for development uses, design diversion structures and culverts, assess environmental impacts of development for the tract area and Piceance Creek hydrologic basin, develop monitoring plans for the development phase, and to plan meaningful mitigation and habitat enhancement procedures.

Piceance Creek Basin can be defined in terms of its geologic characteristics, or in terms of its hydrologic characteristics. The Piceance Creek geologic basin includes parts of Rio Blanco, Garfield, Moffat, Gunnison and Mesa Counties (Figure 2.1).

The Piceance Creek Hydrologic basin is bounded on the north by the White River, on the east by Colorado Highway Number 13, on the south by the Roan Plateau and on the west by Cathedral Bluffs (Figure 2.1). Thus for example, Parachute Creek watershed is part of the geologic basin, but not the hydrologic basin.

The water resource surveys conducted during the baseline period were concentrated in the area of planned development-- Tract C-a (Figure 2.1), which lies on the west-central portion of Piceance Creek hydrologic basin. Exact locations of monitoring holes and surface water sampling stations have been presented in previous RBOSP progress reports. General locations of sampling sites are shown in Figure 2.2.

Physical and chemical studies of surface water resources were conducted at selected locations on Tract C-a and on drainages upstream and downstream from the tract (see Figure 2.2). Studies included continous measurements of flow, specific conductance, water temperature precipitation and sediment.

Analysis of specified nonorganic and organic constituents were made in conjunction with biotic studies. Biological studies included plankton, periphyton, benthos, macrophytes and fish.

Interactions among hydrologic and aquatic biological and abiotic parameters in the Tract C-a study area are described in Section IV of this report.

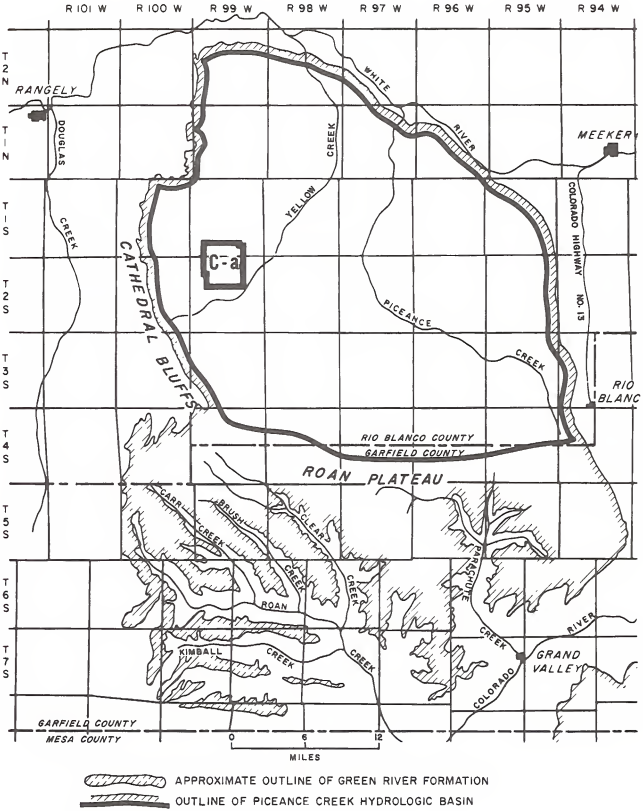


FIGURE 2.1
PICEANCE CREEK HYDROLOGIC BASIN

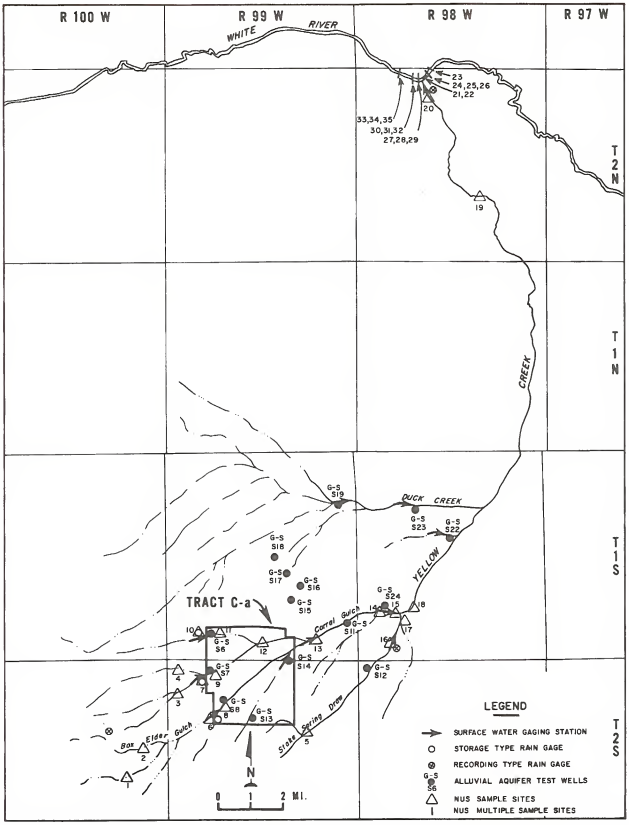


FIGURE 2.2
LOCATIONS OF SAMPLING SITES

CHAPTER 1 - SURFACE WATER HYDROLOGY

ABSTRACT

The Surface Water Hydrology Baseline Data Collection Program was conducted from March 1974 through September 1976, to satisfy the lease stipulation to define stream flow (both quality and quantity), locations of springs, and amount and distribution of rainfall. Flows have been continually monitored with a network of seven stream gaging stations during the baseline period. At these stations, temperatures and specific conductance were continuously monitored and recorded and automatic sediment samplers were operated. Precipitaiton data were supplied by three recording and three storage gages on and around Tract C-a. These data indicate that the average precipitation on Tract C-a is about 10 to 13 inches per year with the maximum amounts falling in the spring and summer seasons. Thirty-seven springs and seeps were identified. Six of these springs were periodically monitored for velocity and quality. Most of the springs are fed by alluvial or shallow bedrock aquifers. Stream flow of Corral Gulch near the eastern border of the tract in the lower reaches of Yellow Creek is sustained by groundwater discharge. Stream flow of Corral Gulch near the western border is supplied most of the year by a spring located above the sampling station. Most runoff results from snowmelt. Intense summer precipitation events are an important source of surface water runoff. Water quality, as indicated by specific conductance, generally worsens from the headwaters downstream. Highest average specific conductance values occur during the winter before snowmelt begins. Water temperatures follow seasonal trends while suspended sediment loads are generally related to flow and rate of change of flow.

The determination of the hydrologic baseline is required for both environmental and engineering studies pertinent to the development of Tract C-a. In addition, the lease stipulates that parameters for surface flow, including

both quantity and quality in stations located on the major drainages upstream and downstream of Tract C-a, shall be monitored for a period of at least two years. Data collected on a continuous basis were flow, water temperature, precipitaion, and sediments load. The lease further stipulated that periodic analysis for inorganic and organic constituents as directed by the mining supervisor (AOSS) would be completed. The AOSS also required that a spring and seep inventory be conducted. The surface water hydrology studies were conducted to determine chemical and physical characteristics, including ranges, variations, and interrelationships, of surface waters on and around Tract C-a.

SURFACE WATER RESOURCES

I. PRECIPITATION

During baseline studies, the USGS operated six rain gaging stations on and around Tract C-a (Figure 2.2). Three were storage type rain gages (associated with the stream gaging stations). One was near the west line of Tract C-a on Dry Fork, one was at Box Elder Gulch, and one was at Corral Gulch. Precipitation was collected from these stations and manually measured at regular intervals. The remaining three rain gages were recording-type gages which record cumulative precipitaion as well as the precipitation rate over minimum five-minute increments. Topographically, the highest of these recording stations was the one west of the tract near the drainage divide on Cathedral Bluffs. The second highest was located near the surface water gaging station at Stake Springs Draw near its confluence with Corral Gulch about three miles east of Tract C-a. The third highest was at the surface water gaging station on Yellow Creek near the White River. This is about 18 miles north-northeast of the Tract.

Precipitation data for 1975 and 1976 are shown in Table 2.1. Figure 2.3 is a histogram depicting monthly precipitation at each of the stations during the baseline period.

TABLE 2.1

SUMMARY OF PRECIPITATION DATA FOR WATER YEARS 1975 AND 1976

Location of Stations	Water Year 1975 Monthly (inches)					Water Year 1976 Monthly (Inches)				
Storage-Type Rain Gage Locations *	Number of Months	Maximum	Minimum	Average	Total	Number of Months	Maximum	Minimum	Average	Total
Dry Fork near West Line Tract C-a	9	1.42	.27	.62	5.61	8	2.01	.87	1.14	9.12
Box Elder Gulch near West Line Tract C-a	9	1.39	.36	.77	6.92	8	2.28	.82	1.12	8.99
Corral Gulch near West Line Tract C-a	9	1.40	.35	.69	6.22	10	1.79	.58	.92	9.19
Recording-Type Rain Gage Locations										
Cathedral Bluffs Located in NW¼, NW¼, Sec. 14, T2S, R100W	12	2.87	.43	1.36	16.30	12	2.49	.40	1.44	17.25
Stake Springs Draw near Confluence with Corral Gulch**	11	2.43	.06	1.09	12.05	12	1.79	.13	1.01	12.11
Yellow Creek near White River***	10	1.67	.04	.95	9.48	12	1.91	.29	.89	10.72

* Start of Record January 1975, Data Not Collected From Storage Gages During Winter, 1976
** Start of Record November 1974
*** Start of Record December 1974

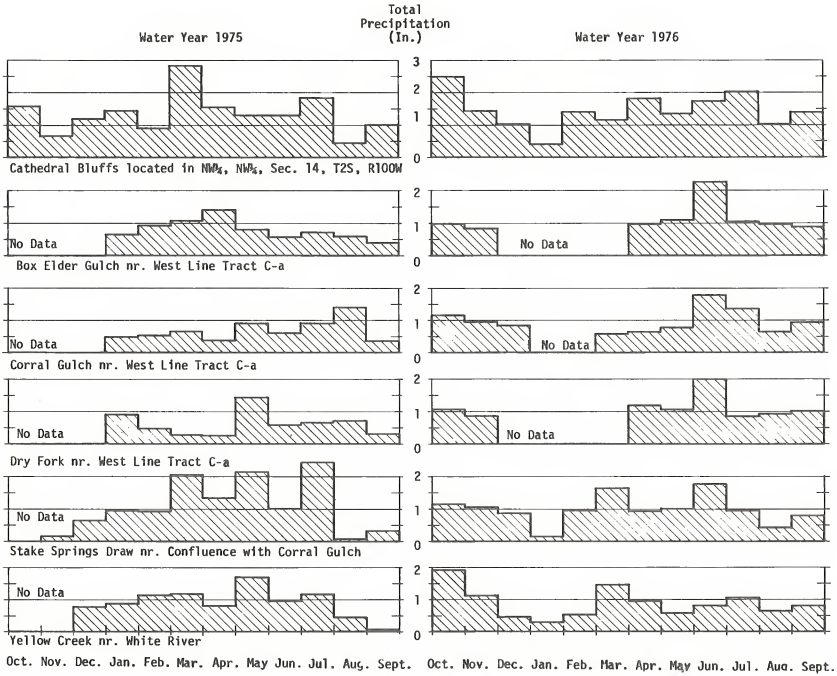


FIGURE 2.3

MONTHLY PRECIPITATION TO[illegible], WATER YEARS 1975, 1976

The precipitation data from the gaging stations indicate a range of 10.7 to 17.2 inches of precipitation per year as shown on Table 2.2. Table values are based on adjusted values due to storage gage evaporative losses and due to irregular data recording during heavy precipitation events and, therefore, represent most probable values over the baseline period.

TABLE 2.2

PRECIPITATION SUMMARY
WATER YEARS 1975 and 1976

Location	1975			1976		
	Monthly Maximum	Monthly Minimum	Total	Monthly Maximum	Monthly Minimum	Total
Cathedral Bluffs	2.87	0.43	16.30	2.49	0.40	17.25
Tract C-a[1]	2.10	0.16	13.25	1.97	0.12	11.83
Yellow Creek	1.67	0.04	10.85	1.91	0.29	10.72

[1]1975 values are from Stakes Springs Draw data; 1976 values represent the averages of Dry Fork, Corral Gulch, Bod Elder Gulch and Stake Springs Draw data.

Two basic weather systems affect precipitation in the study area. The frontal system generally results in widespread, uniform precipitation. The convection system or thunderstorm results in erratic precipitation amounts over an area of a few square miles. The duration of the frontal system precipitation could be a week or so. The thunderstorm duration is usually measured in minutes or hours.

Figure 2.4 is a chart for forecasting the rainfall frequency, duration, and amounts expected in the Tract C-a area. It can be useful in predicting unusual precipitation events despite lack of long term data for the area.

The July 9, 1975 storm recorded at the Stake Springs Draw recording station indicates heavy precipitation for a short period of time. Figure 2.4 indicates that a storm of this intensity occurs every two to five years. A total of 1.19 inches fell during a 13-hour period. This storm also produced the highest intensity recorded during baseline with 0.16 inches and 0.25 inches during a 5- and 10-minute period, respectively. During a 45-minute period, 0.51 inches of rain were recorded, which was the largest single continuous precipitation event reported during the 25 months of data for all of the stations.

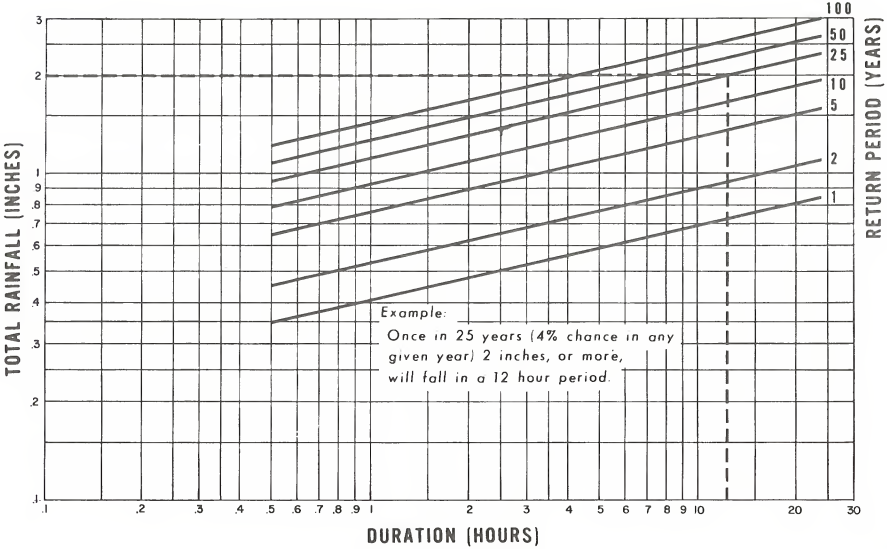


FIGURE 2.4

RAINFALL DEPTH, DURATION, FREQUENCY DIAGRAM

(from U. S. Dept. of Commerce, Weather Bureau, Tech. Paper #40)

II. SPRINGS AND SEEPS

Thirty-seven springs and seeps have been inventoried in the Tract C-a area (Figure 2.5). Some of these show intermittent or seasonal flows; more than 50 percent have perennial flows. These flows may have several origins, such as alluvial aquifers, perched aquifers, the upper oil shale aquifer, or the lower oil shale aquifer. Of the thirty-seven springs and seeps, six were studied in detail. The data from these six springs and seeps were collected as part of the thirty-five aquatic resources samplings sites. These six stations were selected because they were the only ones from which the water came exclusively from the spring source. Three methods were used to compare the physical data from the springs:

- Method 1 - A comparison of the potentiometric surface of the upper aquifer with the elevation above sea level of the spring.
- Method 2 - A statistical analysis of the flow velocity.
- Method 3 - The correlation of flows from one spring to another for a given time period.

The results of these three analyses are given in Table 2.3. The conclusions which can be drawn are that the springs at Stations 1 and 2 have as their water source the alluvial aquifer, and the remaining stations, 3, 4, 5, and 8 derive their spring water from the upper oil shale aquifer.

TABLE 2.3

SUGGESTED SOURCE OF SPRING WATER

Station	Method 1	Method 2	Method 3
1	Alluvial	Alluvial	Alluvial
2	Upper Aquifer	Alluvial	Alluvial and Upper Aquifer
3	Upper Aquifer	Upper Aquifer	Upper Aquifer
4	Upper Aquifer	Upper Aquifer	Upper Aquifer
5	Upper Aquifer	Upper Aquifer	Upper Aquifer
6	Upper Aquifer	Upper Aquifer	Upper Aquifer

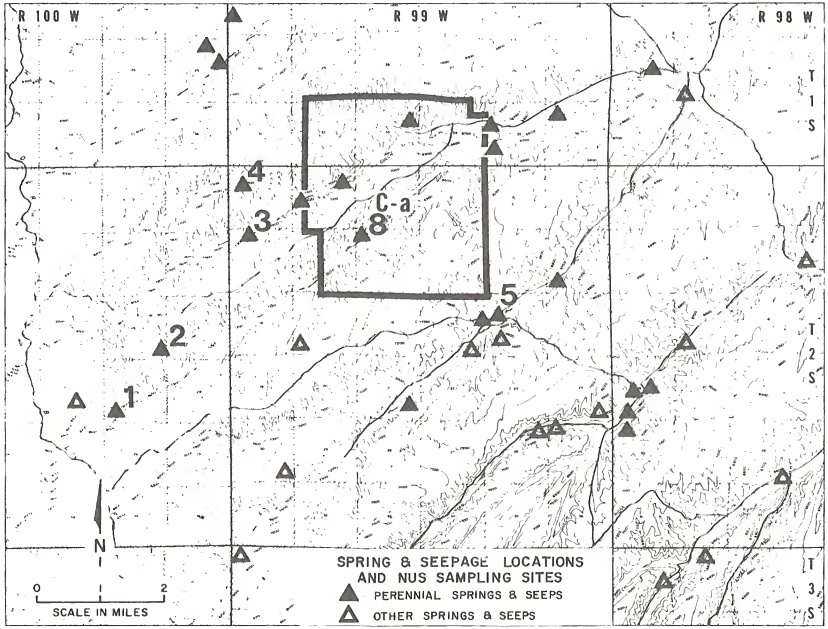

R 100 W
R 99 W
R 98 W
T 1 S
T 2 S
T 3 S
C-a
1
2
3
4
5
8
N
0
1
2
SCALE IN MILES
SPRING & SEEPAGE LOCATIONS
AND NUS SAMPLING SITES
PERENNIAL SPRINGS & SEEPS
OTHER SPRINGS & SEEPS

FIGURE 2.5

III. STREAMS

Water flow has been continually monitored at six gaging stations since March 1974 (Figure 2.2). Specific conductance and temperature were monitored periodically from March 1974 to November 1974, at which time continuous monitoring equipment for specific conductance and temperature was installed at the six stations. The seventh gaging station, located at the mouth of "Rinky Dink" Gulch, was installed in November 1974. The location of these gaging stations is shown of Figure 2.2 and their USGS number and tributary areas are given on Table 2.4. Each station consists of a control weir built across the stream for measuring discharge. In addition to the flow rate, temperature and conductivity are continuously monitored by automatic recording equipment.

Automatic sediment samplers were installed at each station to collect data on sediment concentrations in stream flow. In areas of relatively steady stream flows, samplers are programmed to take samples at regular intervals. In areas subject to rapidly changing stream flows, the samplers are programmed to collect samples every few minutes during a storm event.

Table 2.5 is a surface gaging station flow and sampling summary for the baseline periods. It should be noted that all seven stations were reported to have flow. However, only two of these stations, Corral Gulch east of Tract C-a and Yellow Creek near the White River, had continuous flows. Although Corral Gulch near the west line of Tract C-a and Box Elder Gulch near the west line of Tract C-a did not have perennial flows, they did have flows recorded for at least a portion of the three years of record, as shown on Table 2.5.

Also shown are the months during which a sample or samples were collected at each of the seven gaging stations. It should be noted that flow was recorded in very minute amounts during the months of March and April 1976. However, during these very brief intervals of flow, i.e. a period of a few hours, a sample was not collected. It was learned through the recording instruments that there had been flow and had there been someone in the field at the time, a sample would have been collected.

TABLE 2.4

GAGING STATION IDENTIFICATION NUMBERS
AND DRAINAGE AREAS

USGS I.D. No.	Location	Drainage Area Square Miles
09306237	Dry Fork near west line Tract C-a	2.91
09306235	Corral Gulch near west line Tract C-a	8.44
09306240	Box Elder Bulch near west line Tract C-a	10.29
09306242	Corral Gulch east of Tract C-a	29.59
09306230	Stake Springs Draw near confluence with Corral Gulch	31.61
09306255	Yellow Creek near White River, Colorado	262.00
09306241	"Rinky Dink" Gulch near east line Tract C-a	2.25

TABLE 2.5

SURFACE GAGING STATION FLOW AND SAMPLING SUMMARY

TRACT C-a

Location	1974										1975												1976									
	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May.	June	July	Aug.	Sept.
Dry Fork near West Line Tract C-a													I												I	I					
Corral Gulch near West Line Tract C-a	I S	X S	X S	X S	X S	X S	X S	X S	X S	I	S		I	X S	X S	X S	X S	X S	X S	X	X S	X	I S			X	X S	X S	X S	X S	X S
Box Elder Gulch near West Line Tract C-a		I S	X S	I S										I	X S	I S								I	I S	I	I S	I S			
Corral Gulch East of Tract C-a	I S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S
Stake Springs Draw near Confluence w/Corral Gulch																								I S	I						
Yellow Creek near White River, Colo.	X	X	X S	X S	X S	X S	X S	X S	X	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S	X S
"Rinky Dink" Gulch near East Line Tract C-a												I	I											I S							

X Flow recorded during entire month

I Intermittent flow recorded during month

S Sample collected during month

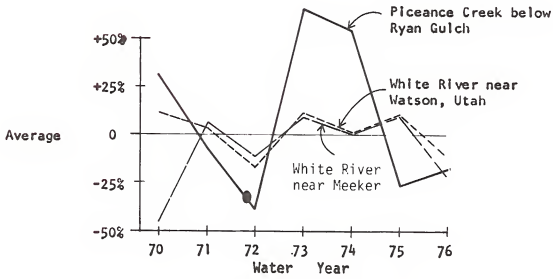
In order to evaluate the baseline surface water program, a comparison of flows was made among Piceance Creek below Ryan Gulch, the White River near Meeker, and White River near Watson. The results of this comparison are shown on Figure 2.6. It should be noted that Piceance Creek below Ryan Gulch showed significant increases in base flow during water years 1973 and 1974. In fact, a significant increase was recorded in May 1973 as shown on Figure 2.7, the same month in which Project Rio Blanco was detonated. It is probable that the nuclear detonation may have affected surface water base flows from the time of detonation to the present throughout the Piceance Creek basin. Unfortunately, there are not the data for Yellow Creek near the White River that there are for Piceance Creek. Therefore, it is impossible to conclude at this time what the effects may have been on Yellow Creek except by analogy with Piceance Creek.

A summary of the continuously or automatically monitored surface water data for water years 1975 and 1976 is shown on Table 2.6. There have not been enough data collected on Dry Fork, "Rinky Dink", or Stakes Springs Draw gaging stations to present meaningful data on such a table. Generally, the water quality is shown to decrease in the downstream direction.

The monthly mean flow for each of the seven surface water gaging stations is shown on Figure 2.8 for water years 1975 and 1976. A summary of the annual runoff in acre-feet per year is given in Table 2.7.

Since inflows and outflows are measured for drainages traversing Tract C-a, it is possible to evaluate the quantity of surface water origination on tract. The quantity of water measured at Dry Fork near west line of Tract C-a, Corral Gulch near west line of Tract C-a, Box Elder Gulch near west line of Tract C-a, and "Rinky Dink" Gulch near east line of Tract C-a, plus the amount of water supplied by the tract will equal the discharge at Corral Gulch east of Tract C-a. This water comes from spring and diffuse groundwater discharge, detention storage released from the alluvium, snowmelt, and storm runoff on the tract. Monthly balances were completed for the period April 1974 through June 1975 and are shown on Figure 2.9.

PERCENT DEVIATION
OF
REGIONAL STREAM RUNOFF VOLUMES
from USGS Data



White River near Meeker, Colo. 09304500, mean flow 450,600 A-F/year 65 yrs.
White River near Watson, Utah 09306500, mean flow 508,600 A-F/yr. 51 yrs.
Piceance Creek below Ryan Gulch, mean flow 12,360 A-F/yr. 11 yrs.

FIGURE 2.6
DEVIATION OF REGIONAL STREAM
RUNOFF VOLUMES

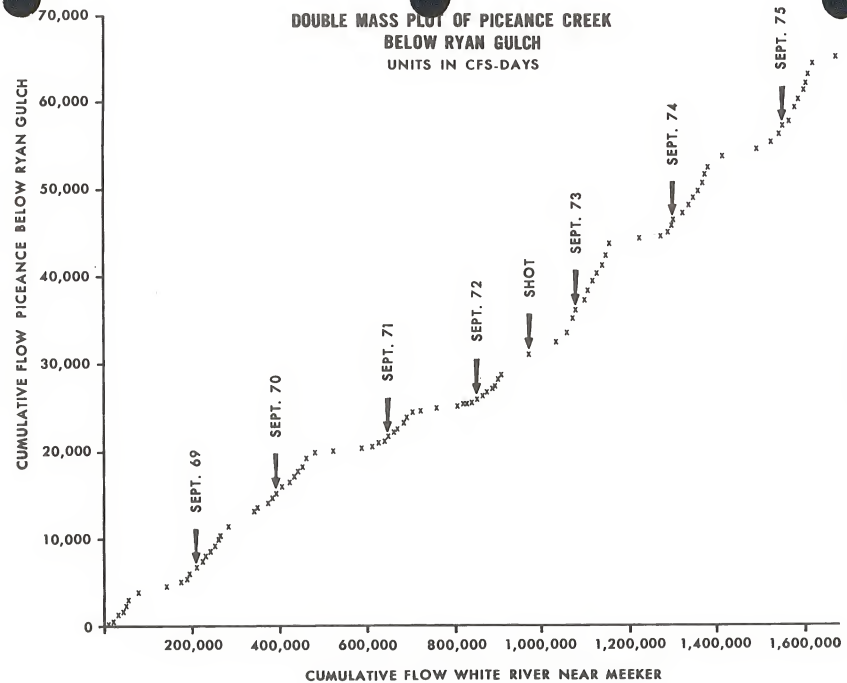


FIGURE 2.7
PICEANCE CREEK BASEFLOWS 1969 - 1975

TABLE 2.6

SUMMARY OF CONTINUOUSLY MONITORED SURFACE WATER DATA

FOR WATER YEARS 1975 AND 1976

Station	Parameter*	Maximum Value	Minimum Value	Arithmatic Mean	Standard Deviation	Median Value
Corral Gulch near west line Tract C-a	Specific Conductance (μmhos/cm)	1330	752	1043	115	1060
	Temperature (C)	33.1	0.5	14.8	5.97	15.45
	Flow (cfs)	0.74	0	0.18	0.17	0.17
	Sediment Discharge (tons/day)	16.0	0	0.18	0.94	0.01
Box Elder Gulch near west line Tract C-a	Specific Conductance (μmhos/cm)	891	595	775	73.4	784
	Temperature (C)	17.5	5.5	11.3	2.51	11.1
	Flow (cfs)	2.9	0	0.20	0.59	< 0.01
	Sediment Discharge (tons/day)	21	0	1.75	4.12	0.08
Corral Gulch East of Tract C-a	Specific Conductance (μmhos/cm)	2050	761	1272	187	1250
	Temperature (C)	22.0	5.0	10.2	2.52	10.3
	Flow (cfs)	5.6	0.06	0.73	0.57	0.54
	Sediment Discharge (tons/day)	240	0.01	2.60	14.84	0.10
Yellow Creek near White River, Colo.	Specific Conductance (μmhos/cm)	5080	1410	3532	568	3581
	Temperature (C)	25.0	0	12.1	6.67	14.0
	Flow (cfs)	13.0	0.23	1.87	1.3	1.70
	Sediment Discharge (tons/day)	800	0.01	4.72	30.2	0.60

* Daily mean values

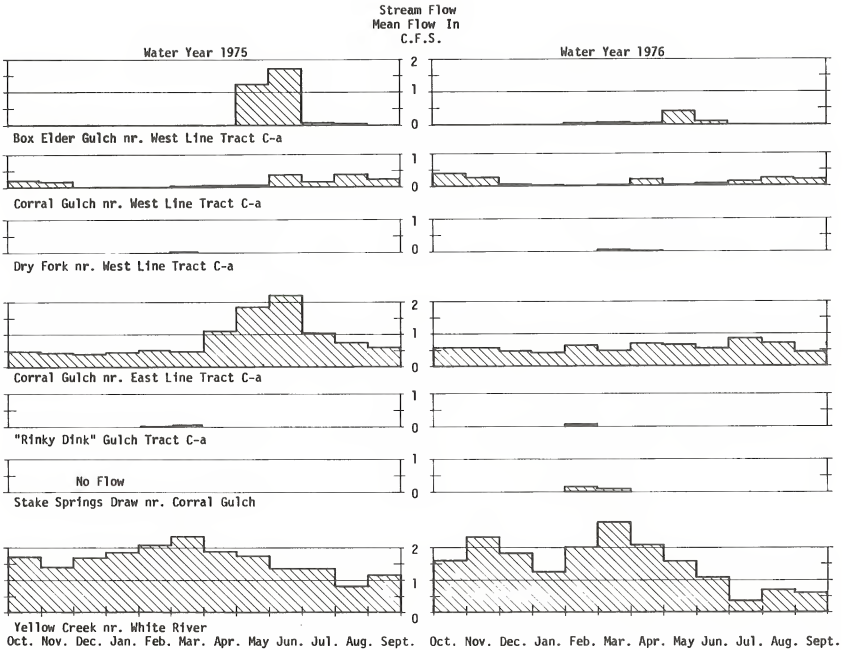


FIGURE 2.8

MONTHLY MEAN FLOWS AT SEVEN GAGING STATIONS, WATER YEARS 1975 and 1976

TABLE 2.7

ANNUAL RUNOFF IN ACRE-FEET

STATION	WATER YEAR 1974*	WATER YEAR 1975	WATER YEAR 1976
Dry Fork near west line Tract C-a	1.4	0.2	4.3
Corral Gulch near west line Tract C-a	134.0	96.7	98.5
Box Elder Gulch near west line Tract C-a	148.4	182.8	34.8
Rinky Dink Gulch near east line Tract C-a	no data	0.6	2.3
Corral Gulch near east line Tract C-a	309.3	626.2	418.1
Stake Springs Draw near Confluence with Corral Gulch	0.0	0.0	15.5
Yellow Creek near White River	1740**	1158.7	1103.1

* March through September only.
** Complete Records for Water Year 1974.

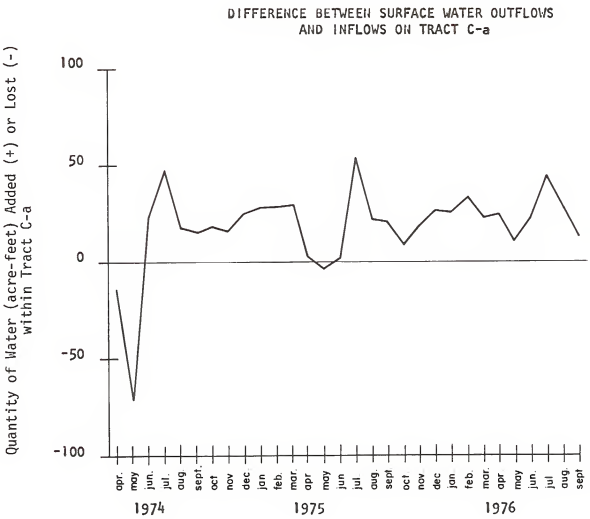


FIGURE 2.9
COMPARISON OF SURFACE WATER INFLOWS
AND OUTFLOWS, 1974 - 1976
TRACT C-a

The most distinctive property of additions to surface water flow on Tract C-a is that a peak occurs following snowmelt runoff. This peak is due to storage within the alluvial aquifer that discharges for some time after peak flow. During the peak flow periods at the inflow stations, runoff within the tract is generally at a low point due to infiltration of the runoff into the alluvium in the upper reaches of gulches.

The data collected to date indicate that one major source of stream flow is snowmelt runoff. This runoff period is highly variable and has begun as early as February and as late as April. Based on three years of data, stream recession curves have been calculated and constructed. These curves indicate the time in days for the stream to return to normal flow after the highest flow has occurred at a given gaging station, as shown on Figure 2.10.

Histograms of numerous constituent concentrations were plotted and many showed a distinct right skewness. When the data were plotted in log form, the normal Gaussian curve was more closely approximated as shown on Figure 2.11. Therefore, the vast majority of the statistical analyses were conducted using the logarithmic format.

Based on available data from March 1974 through September 1976, duration curves were developed for flow, temperature, specific conductance, and suspended sediment load. Figures 2.12, 2.13, 2.14, and 2.15 show these curves for the four stations from which sufficient data were available. Duration curves show the probability of equalling or exceeding given values. The distinctive feature of these curves is the similarity of Corral Gulch east and Yellow Creek. Both have sustained base flow for the period of record and are generally parallel, with Yellow Creek showing higher discharges. Box Elder and Corral Gulch west don't sustain a base flow; however, both show distinctive breaks in slope in the duration curve at higher discharge which indicate the effects of snowmelt.

A statistical evaluation was made comparing the continuously or automatically recorded data. The scattergram shown on Figure 2.16 is the result of plotting log values for two parameters. These values were analyzed statistically using the least squares method resulting in slopes and straight line equations.

STREAM RECESSION CURVES

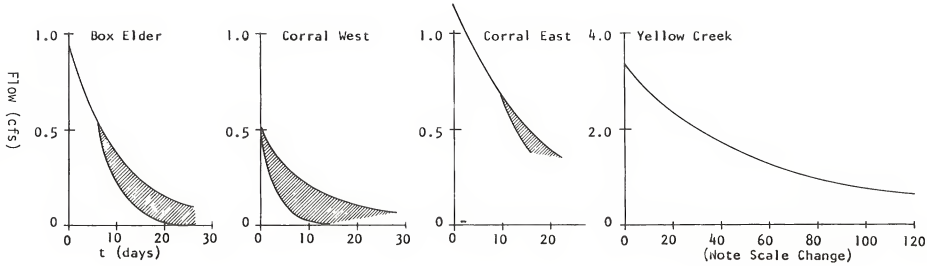


FIGURE 2.10

STREAM RECESSION CURVES

(Variation in range shown by cross-hatching)

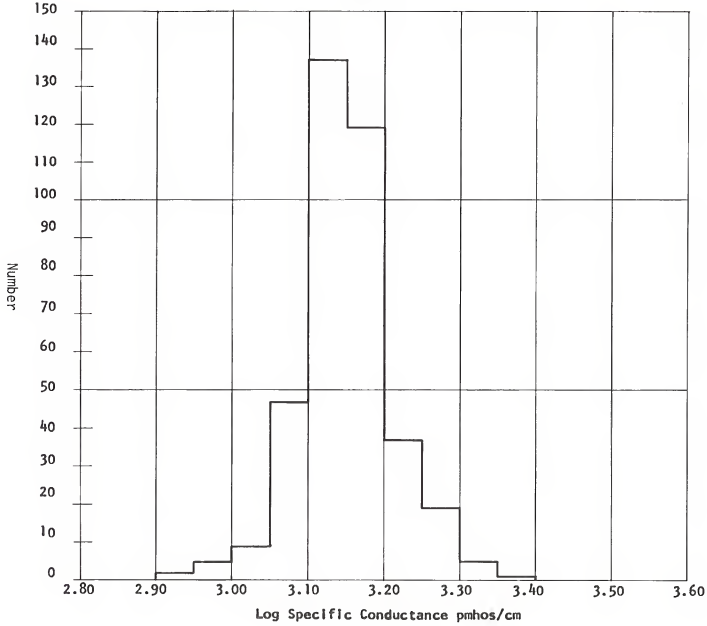


FIGURE 2-11

DATA DISTRIBUTION FOR LOG SPECIFIC CONDUCTANCE, CORRAL GULCH

NEAR EASTERN BORDER OF TRACT C-a

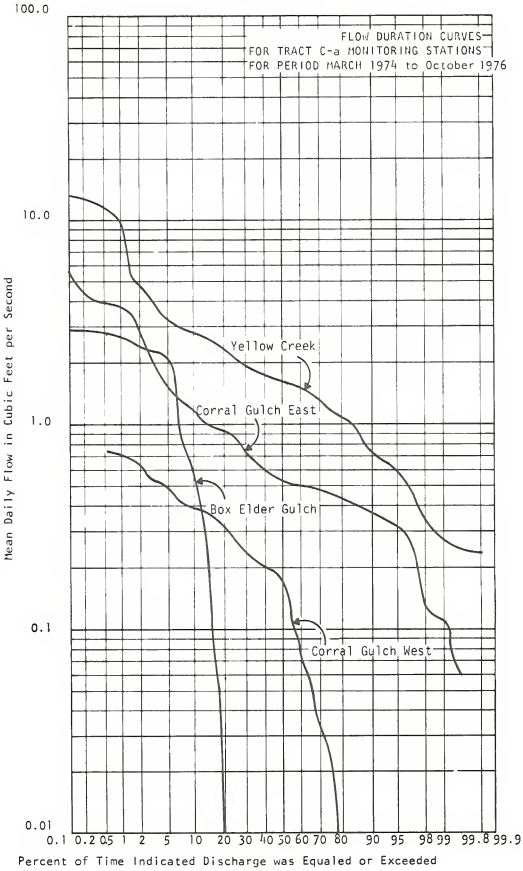


FIGURE 2.12

FLOW DURATION CURVES, TRACT C-a, MARCH 1974 - OCTOBER 1976

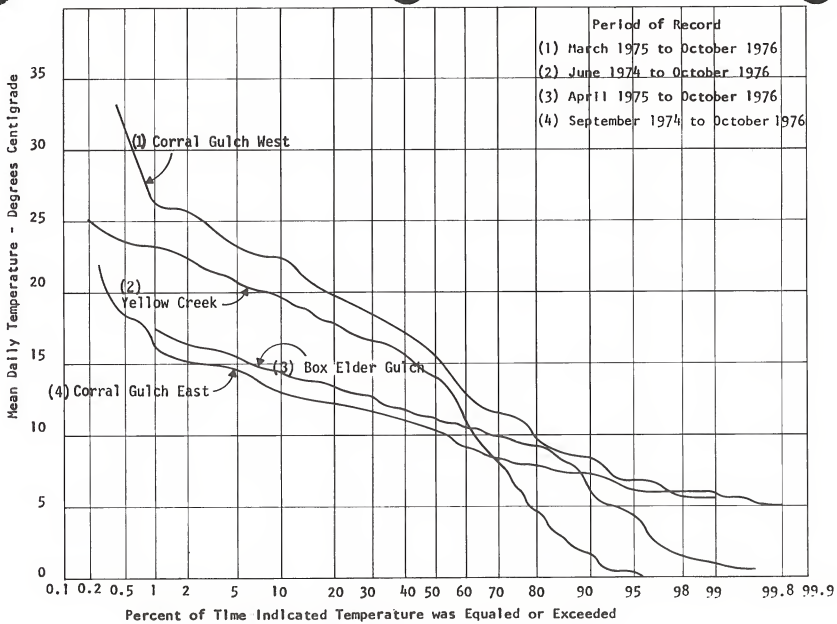


FIGURE 2.13

MEAN DAILY TEMPERATURE DURATION CURVES, TRACT C-a

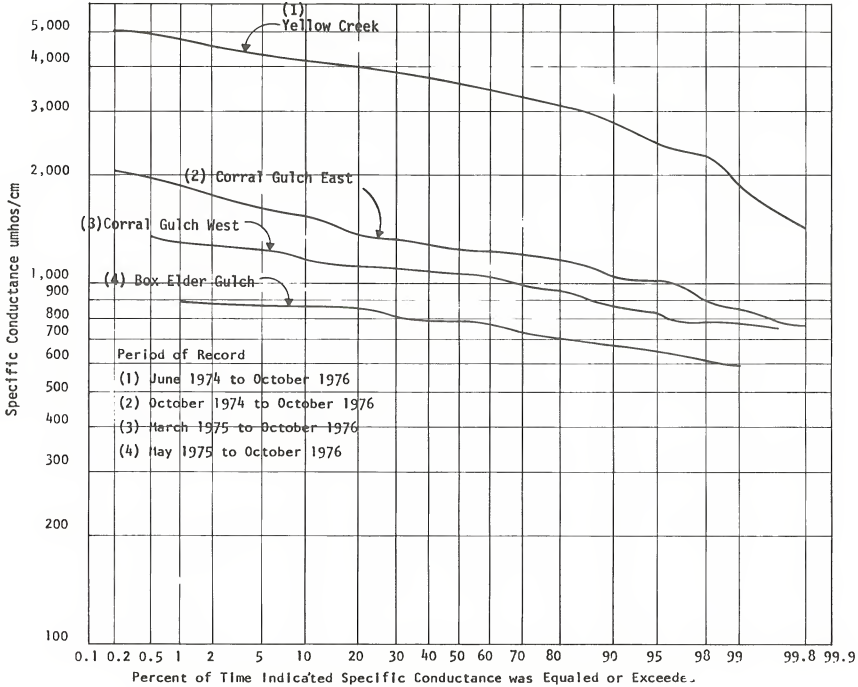


FIGURE 2.14

DATA DISTRIBUTION FOR SPECIFIC CONDUCTANCE,
CORRAL GULCH NEAR EASTERN BORDER OF TRACT C-a

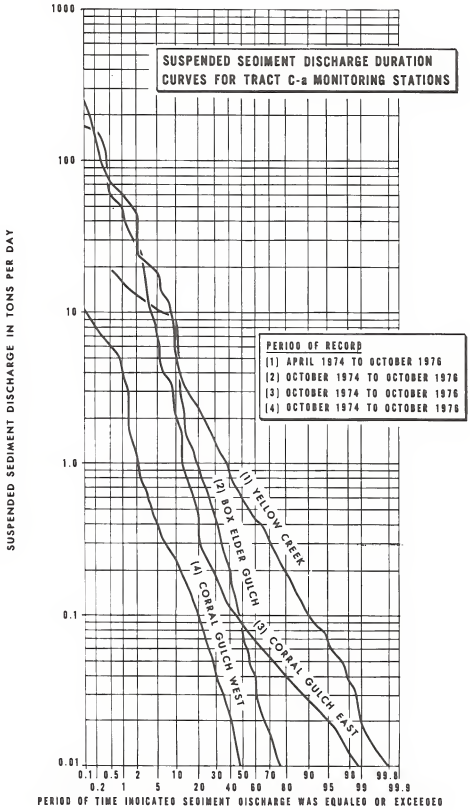
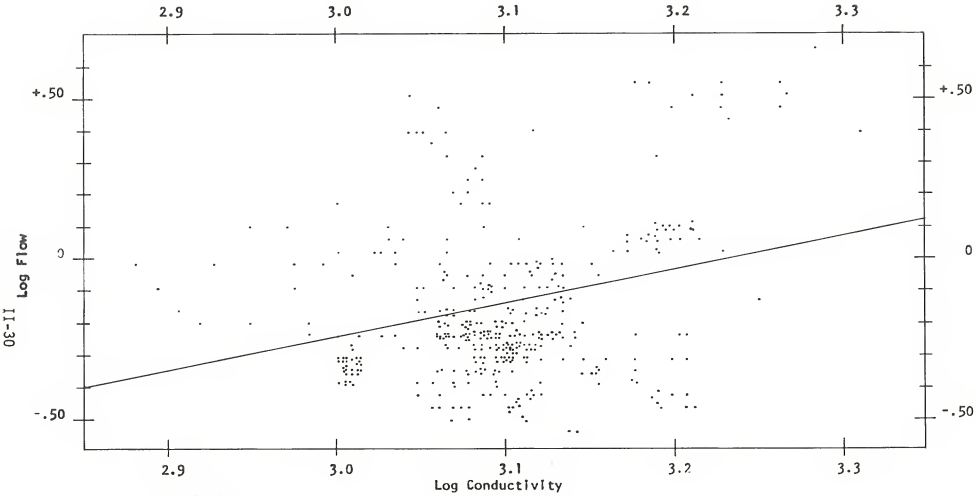


FIGURE 2.15

SUSPENDED SEDIMENT DISCHARGE DURATION CURVES



Statistics
Log Flow = -3.46 + 1.07 Log Conductivity
Standard Error of Estimate .23
Correlation Coefficient .28

FIGURE 2.16

RELATIONSHIP BETWEEN LOG FLOW AND LOG CONDUCTIVITY AT CORRAL GULCH NEAR EASTERN BORDER OF TRACT C-a

The standard error of estimate and correlation coefficients indicate how well the data actually fits the calculated straight line equations.

Table 2.8 titled "Selected Correlations of Continuous Parameters for Tract C-a Monitoring" compares several parameters in pairs. They are log flow with conductivity, log flow with log sediment load, and log conductivity with log sediment load. The values indicated are correlation coefficients in which the possible range can vary from -1 to +1. A perfect fit of the data to the calculated linear equation would result in a value of 1. A value greater than -1 or less than 1 indicates something less than a perfect fit of the data. For example, the Corral Gulch near the east line of Tract C-a, a comparison of the data indicates a high probability that when flow increases the suspended sediment load will also increase.

In summary, the four stations, with the exception of Yellow Creek near the White River, based on the two years of baseline data were found to have conductivity increase as flow increased. On the Yellow Creek gaging station the conductivity decreased as flows increased. This relationship is expected in that the base flows on Yellow Creek are highly saline because of the deep oil shale aquifers' contribution to Yellow Creek flows near the White River. On each of the four stream gaging stations, the data indicated that suspended sediment load increased with flow.

CONCLUSIONS

Based on the two years of baseline data, Tract C-a received approximately 12 to 13 inches of precipitation annually. As indicated by the three recording-type precipitation gages, the greatest amount of precipitation falls along Cathedral Bluffs and the lowest amount falls at the confluence of Yellow Creek and the White River.

Of the thirty-seven springs and seeps inventoried, six were studied in detail. Five of these six stations were found to have a distinctive water source, i.e. the alluvial or upper aquifer.

Table 2.8

SELECTED CORRELATIONS OF CONTINUOUS PARAMETERS
FOR TRACT C-a MONITORING STATIONS
(Significant at the 5% Confidence Level)

Location	Log Flow With Log Conductivity	Log Flow With Log Suspended Sediment Load
Corral Gulch near west line Tract C-a	0.19	0.16
Box Elder Gulch near west line Tract C-a	0.30	0.74
Corral Gulch near east line Tract C-a	0.28	0.82
Yellow Creek near White River	-0.38	0.64

Three of the seven surface water gaging stations were found to flow during most of the period of record. These three stations are Corral Gulch near the west line of Tract C-a, Corral Gulch east of Tract C-a, and Yellow Creek near the White River, Colorado. The remaining four streams were found to have flows only during spring snowmelt runoff. In general, the streams were found to be intermittent with a few reaches having perennial flows due to groundwater discharge.

CHAPTER 2 - SURFACE WATER QUALITY

ABSTRACT

As required by the Area Oil Shale Supervisor, water quality analyses have been made on the surface water collected from the surface water gaging stations located on and around Tract C-a. In addition, a more limited sampling program has been conducted at an additional 37 sites, some of which are as far away as the White River. In order to give meaningful results related to the approximately 750 water samples, from which several thousand analyses were conducted, statistical methods were used. At each of the sampling points, a high, low, geometric mean, and geometric deviation are given for each of the constituents. In addition, where more than one laboratory was used for these analyses, a comparison is made between the two. The results of the analyses are compared with standards for range animals and the United States Public Health Service (USPHS) for drinking water quality. Trilinear diagrams were used to plot combinations of chemical constituents from various water sources. In addition, it was found that various constituents could be categorized into unique factors or groups. These factor score values were then plotted versus time.

As required by the Tract C-a Oil Shale Lease Environmental Stipulations, periodic water samples were collected and were analyzed for select inorganic and organic chemical constituents as directed by the AOSS. These samples were to be collected both upstream and downstream of Tract C-a. As part of these conclusions, the determination of probable areal-time variation and interrelationship between parameters is an additional objective of the surface water quality program.

WATER QUALITY

To estimate long-term expected ranges in chemical parameters, a statistical model was chosen to identify the population of chemical concentrations in streamflow at a station. Histograms of numerous constituent concentrations

were plotted and most showed a distinctive right-skewness. The tendency of natural water quality toward a right-skewed frequency distribution has also been found by several other investigations and the standard practice is to assume that the population of chemical concentrations is best described by the log-normal distribution (Davis 1966).

The hypothesis that the frequency distributions are log-normal was tested using chi squared, a technique of objective comparison of shapes of the theoretical frequency distribution with one derived from observed data. Since the observed probability densities did not follow the ideal log-normal distribution, the method of non-linear least squares (as described by Snyder 1972). was used to estimate the parameters of the probability density function. This method minimizes the difference in a calculated probability density function from the observed histogram of relative frequencies. It has the advantage that threshold values (reported as less than a sensitivity limit) can be incorporated without biasing the sample. The observed data were first transformed into normal form by taking the log to base 10 and constructing a histogram of this normalized data. Only pH and temperature were not transformed since pH is already expressed as a log value and temperature tends to be normally distributed.

Probabilistic determination of expected water quality based on data collected during the baseline monitoring program will allow projections of expected ranges in water quality in future years, assuming that the proportion of stream flow components acting during the sampling period are representative of long-term variations. As shown in the previous chapter (Chapter 1 - Surface Water Hydrology), runoff quantities in the baseline period range from somewhat above normal to below normal, so the baseline period may approximate long-term variations.

I. PRECIPITATION

No data on precipitation water quality were collected during the baseline period in the aquatic resources program.

II. SPRINGS AND SEEPS

Discrete and diffuse groundwater discharge from springs and seeps affects the quality of surface water. Studies conducted to determine these sources were discussed in Chapter 1 of this section. Water quality samples were taken with the same frequency and at the same locations as physical data to maintain continuity.

The aquatic resources program included six monitoring sites on streams below spring and seepage areas. Table 2.9 summarizes ranges, means, and geometric deviations for these stations. The station locations are shown on Figure 2.2.

Ranges in water quality types for the eight monitored springs and seeps are shown on a trilinear diagram (Figure 2.17). Generally, water quality of springs and seeps approximates the quality in the alluvial and upper aquifer. There is conclusive evidence that the lower aquifer does not directly contribute water to any of the springs and seeps that were monitored.

III. STREAMS

Summary tables were prepared for all parameters at each station and best-fit estimates of geometric means and geometric deviations, number of samples they were based on, confidence limits, and points on the probability density curve are presented in RBOSP Progress Report 10. Tables 2.10 through 2.15 show summary statistics for USGS monitoring stations with corresponding aquatic resources program data for comparison. Table 2.16 presents summaries of White River surface water quality. Chi squared goodness-of-fit statistics were derived and over half of the derived curves were acceptable using this criterion at the 5 percent confidence level. Failure to meet this criterion was related to resistant right-skewness evident even after log transformation. The best-fit log-normal distribution was retained as a best estimate for the tables, even though some of the heavy metals may fit one of the extremal type distributions. Analysis error in the determination of trace heavy metal concentrations may also modify the distribution. No data on the standard deviation of lab determination of heavy metal concentrations were available.

TABLE 2.9

BASELINE SPRING AND SEEP WATER QUALITY SUMMARY

Parameter No.	Item	Station 1 High	Station 1 Low	Station 1 Geometric Mean	Station 1 Geometric Deviation	Station 1 No. of Analysis	Station 2 High	Station 2 Low	Station 2 Geometric Mean	Station 2 Geometric Deviation	Station 2 No. of Analysis
71846	Ammonia (NH4)(mg/l)	<0.10	<0.10	<0.10	1.00	18	<0.10	<0.10	<0.10	1.00	20
915	Calcium (mg/l)	97.00	43.00	83.74	1.28	18	102.00	44.00	92.47	1.09	20
940	Chloride (mg/l)	5.90	3.00	4.03	1.05	18	40.00	4.10	5.30	1.33	20
80	Color (PCU)	15.00	2.50	6.97	2.88	18	15.00	2.50	6.28	2.53	20
950	Fluoride (mg/l)	0.32	0.30	0.31	1.05	2	0.49	0.44	0.46	1.08	2
900	Hardness (Ca, Mg)(mg/l)	433.00	336.00	421.20	1.03	18	480.00	320.00	409.96	1.05	20
	Iron										
1046	Dissolved (ug/l)	<0.02	<0.02	<0.02	1.00	2	<0.02	<0.02	<0.02	1.00	2
1045	Total (ug/l)	0.07	0.05	0.06	1.27	2	0.16	0.14	0.15	1.10	2
925	Magnesium (mg/l)	94.00	42.00	48.48	1.28	18	94.00	40.00	45.39	1.09	20
71851	Nitrate (NO 3) (mg/l)	2.00	0.50	0.68	1.36	18	1.10	<0.20	0.36	2.02	20
71856	Nitrite (NO 2) (mg/l)	<0.01	<0.01	<0.01	1.00	18	0.06	<0.01	0.02	2.04	20
99993	Nitrogen (mg/l)	1.10	0.16	0.40	1.90	18	0.37	0.14	0.26	1.33	20
1330	Odor (Severity)	0.00	0.00	0.00	1.00	18	0.00	0.00	0.00	1.00	20
681	Organic Carbon										
	Dissolved (mg/l)	26.00	<1.00	16.11	1.84	36	28.00	<1.00	6.68	2.91	40
	Phosphate										
660	Dissolved (PO 4)(mg/l)	0.03	<0.01	0.01	1.46	18	<0.01	<0.01	<0.01	1.00	20
665	Total (P)(mg/l)	0.18	0.01	0.02	3.06	18	0.11	0.01	0.05	1.94	20
935	Potassium (mg/l)	2.80	0.70	1.25	1.35	18	1.70	0.90	1.17	1.06	20
80154	Sediment, suspended (mg/l)	658.00	<1.00	6.61	8.92	18	62.00	<1.00	15.38	5.19	20
955	Silica (SiO2)(mg/l)	23.21	15.27	20.37	1.27	18	25.68	11.98	23.10	1.10	20
930	Sodium (mg/l)	50.00	35.00	41.48	1.10	18	88.00	44.00	68.29	1.23	20
70301	Solids, Dissolved (mg/l)	607.00	484.00	560.36	1.04	18	764.00	558.00	612.85	1.08	20
945	Sulfate (mg/l)	128.75	104.60	115.19	1.09	18	254.32	128.76	146.18	1.08	20
70	Turbidity (JTU)	125.00	0.30	0.92	2.56	18	9.20	0.20	2.40	3.64	20

Parameter No.	Item	Station 3 High	Station 3 Low	Station 3 Geometric Mean	Station 3 Geometric Deviation	Station 3 No. of Analysis	Station 4 High	Station 4 Low	Station 4 Geometric Mean	Station 4 Geometric Deviation	Station 4 No. of Analysis
71846	Ammonia (NH4) (mg/l)	0.31	<0.10	0.11	1.36	24	<0.10	<0.10	<0.10	1.00	24
915	Calcium (mg/l)	109.00	52.00	86.66	1.18	24	120.00	60.00	107.54	1.06	24
940	Chloride (mg/l)	18.00	5.10	10.77	1.16	24	48.00	6.00	7.42	1.51	24
80	Color (PCU)	35.00	2.50	8.47	3.44	24	35.00	2.50	4.35	3.12	24
950	Fluoride (mg/l)	0.30	<0.10	0.15	1.71	4	0.30	<0.10	0.15	1.71	4
900	Hardness (Ca, Mg)(mg/l)	516.00	260.00	455.72	1.11	24	552.00	279.00	502.56	1.08	24
	Iron										
1046	Dissolved (ug/l)	<0.02	<0.02	<0.02	1.00	4	<0.02	<0.02	<0.02	1.00	4
1045	Total (ug/l)	0.09	0.06	0.08	1.22	4	0.09	0.02	0.05	2.09	4
925	Magnesium (mg/l)	86.00	31.00	56.41	1.17	24	110.00	45.00	60.30	1.05	24
71851	Nitrate (NO 3) (mg/l)	2.00	<0.20	0.24	1.90	24	1.70	<0.20	1.05	1.60	24
71856	Nitrite (NO 2) (mg/l)	0.01	0.01	0.01	1.00	24	<0.10	<0.01	<0.01	1.60	24
99993	Nitrogen (mg/l)	8.50	<0.10	0.41	4.69	24	2.30	0.22	0.29	1.30	24
1330	Odor (Severity)	0.00	0.00	0.00	1.00	24	1.00	0.00	0.00	7.03	24
681	Organic Carbon										
	Dissolved (mg/l)	60.00	<1.00	6.94	2.80	48	42.00	<1.00	9.97	2.51	48
	Phosphate										
660	Dissolved (PO 4)(mg/l)	0.03	0.01	0.01	1.45	24	0.03	0.01	0.01	1.84	24
665	Total (P) (mg/l)	0.30	0.02	0.08	2.95	24	1.20	0.02	0.04	1.85	24
935	Potassium (mg/l)	28.00	2.00	2.48	1.40	24	2.80	1.30	1.86	1.35	24
80154	Sediment, suspended(mg/l)	407.00	1.00	19.86	16.84	24	1100.00	4.00	13.59	2.65	24
955	Silica (SiO2)(mg/l)	23.56	5.56	16.40	1.40	24	21.83	16.26	21.15	1.04	24
930	Sodium (mg/l)	120.00	66.00	106.29	1.08	24	93.00	68.00	84.54	1.07	24
70301	Solids, Dissolved (mg/l)	974.00	476.00	825.09	1.04	24	858.00	419.00	775.39	1.15	24
945	Sulfate (mg/l)	341.36	149.72	289.68	1.08	24	272.49	224.58	261.41	1.03	24
70	Turbidity (JTU)	85.00	0.40	8.91	7.78	24	92.00	0.50	2.98	3.07	24

Parameter No.	Item	Station 5 High	Station 5 Low	Station 5 Geometric Mean	Station 5 Geometric Deviation	Station 5 No. of Analysis	Station 8 High	Station 8 Low	Station 8 Geometric Mean	Station 8 Geometric Deviation	Station 8 No. of Analysis
71846	Ammonia (NH4)(mg/l)	0.10	0.10	0.10	1.00	24	<0.10	<0.10	<0.10	1.00	24
915	Calcium (mg/l)	112.00	84.00	94.79	1.14	24	92.00	66.00	83.16	1.06	24
940	Chloride (mg/l)	14.00	9.00	11.36	1.10	24	12.00	6.00	8.90	1.26	24
80	Color (PCU)	25.00	2.50	8.18	3.38	24	35.00	2.50	4.81	3.73	24
950	Fluoride (mg/l)	0.42	0.10	0.20	2.29	4	0.32	0.30	0.31	1.03	4
900	Hardness (Ca,Mg)(mg/l)	609.00	434.00	568.49	1.06	24	456.00	307.00	425.65	1.05	24
	Iron										
1046	Dissolved (ug/l)	<0.02	<0.02	<0.02	1.00	4	<0.02	<0.02	<0.02	1.00	4
1045	Total (ug/l)	0.08	0.02	0.04	1.83	4	0.08	<0.02	0.03	1.92	4
925	Magnesium (mg/l)	87.00	48.00	77.08	1.16	24	58.00	42.00	52.19	1.06	24
71851	Nitrate (NO 3)(mg/l)	1.40	0.20	0.29	1.96	24	1.10	<0.20	0.45	2.23	24
71856	Nitrite (NO 2)(mg/l)	<0.10	<0.01	<0.01	1.60	24	0.02	<0.01	0.01	1.19	24
99993	Nitrogen (mg/l)	0.66	0.19	0.39	1.60	24	2.00	<0.10	0.23	1.80	24
1330	Odor (Severity)	0.00	0.00	0.00	1.00	24	0.00	0.00	0.00	1.00	24
681	Organic Carbon										
	Dissolved (mg/l)	32.00	<1.00	9.05	3.21	48	34.00	<1.00	9.57	1.96	48
	Phosphate										
660	Dissolved (PO 4)(mg/l)	0.02	<0.01	0.01	1.15	24	0.08	0.01	0.02	1.53	24
665	Total (P) (mg/l)	0.05	0.01	0.02	1.84	24	1.00	0.02	0.03	1.56	24
935	Potassium (mg/l)	4.90	1.90	3.16	1.46	24	2.50	1.30	1.80	1.09	24
80154	Sediment, suspended (mg/l)	44.00	1.00	3.29	4.43	24	1200.00	1.00	2.84	3.39	24
955	Silica (SiO2)(mg/l)	17.12	5.99	11.47	1.30	24	22.26	8.77	19.07	1.25	24
930	Sodium (mg/l)	142.00	120.00	128.06	1.06	24	90.00	55.00	76.94	1.05	24
70301	Solids, Dissolved (mg/l)	1080.00	0.00	550.97	16.71	24	740.00	543.00	680.02	1.05	24
945	Sulfate (mg/l)	446.17	92.83	356.97	1.51	24	221.59	146.73	203.39	1.07	24
70	Turbidity (JTU)	37.00	0.50	1.20	1.53	24	290.00	0.20	0.71	2.5	24

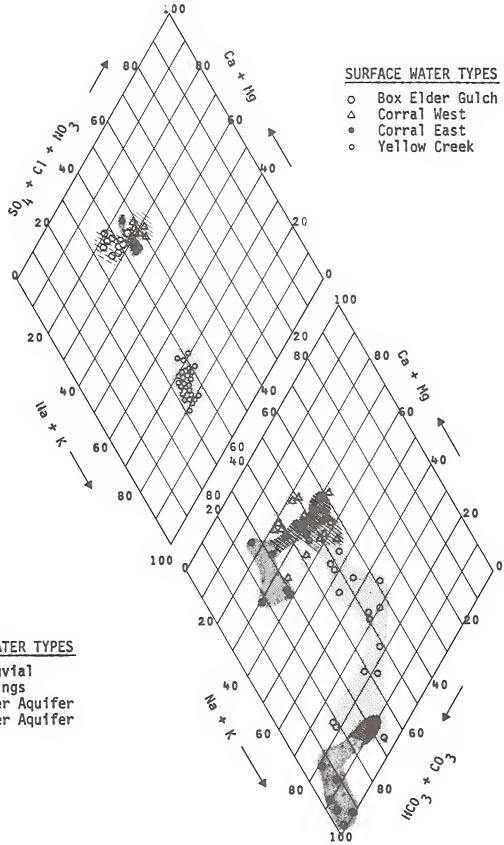


FIGURE 2.17

RANGES IN WATER QUALITY TYPES, TRACT C-a AREA

TABLE 2.10

BASELINE SURFACE WATER QUALITY SUMMARY RINKY DINK GULCH NEAR EAST LINE TRACT C-a

Param. No.	Item	USGS DATA High	USGS DATA Low	USGS DATA Geo. Mean	USGS DATA Geo. Dev.	USGS DATA No. of Analy.	NUS DATA High	NUS DATA Low	NUS DATA Geo. Mean	NUS DATA Geo. Dev.	NUS DATA No. of Analy.
410	Alkalinity (mg/l)	73.00	72.00	72.50	1.01	2					
1106	Aluminum (ug/l)	250.00	250.00			1					
71846	Ammonia (NH_4) (mg/l)	0.12	0.06	0.08	1.63	2					
1000	Arsenic (mg/l)	3.00	3.00			1					
1005	Barium (ug/l)	<50.00	<50.00			1					
1010	Beryllium (ug/l)										
440	Bicarbonate (mg/l)	89.00	88.00	88.50	1.01	2					
1015	Bismuth (ug/l)										
310	BOD (mg/l)										
1020	Boron (ug/l)	100.00	50.00	70.71	1.63	2					
71870	Bromide (mg/l)	0	0								
1025	Cadmium (ug/l)	1.00	1.00			1					
915	Calcium (mg/l)	17.00	11.00	13.67	1.36	2					
445	Carbonate (mg/l)	0	0	0		2					
940	Chloride (mg/l)	1.80	1.70	1.75	1.04	2					
1030	Chromium (ug/l)	1.00	1.00			1					
340	COD (mg/l)	240.00	240.00			1					
31616	Coliform, Fecal (Col/100 ml)										
74050	Coliform, Total (Col/100 ml)										
80	Color (PCU)	20.0	20.0								
95	Conductivity, Spec. (umhos)	190.00	160.00	174.36	1.13	2					
1040	Copper (ug/l)	13.00	13.00			1					
720	Cyanide (mg/l)	0.01	0.01			1					
300	Dissolved Oxygen (mg/l)										
950	Fluoride (mg/l)	0.30	0.20	0.24	1.33	2					
1120	Gallium (ug/l)										
1125	Germanium(ug/l)										
900	Hardness (Ca,Mg) (mg/l)	55.00	37.00	45.11	1.32	2					
1046	Iron (ug/l)	280.00	280.00			1					
625	Kjeldahl Nitrogen (mg/l)										
1049	Lead (ug/l)	10.00	10.00			1					
1130	Lithium (ug/l)	10.00	10.00			1					
925	Magnesium (mg/l)	3.00	2.20	2.57	1.25	2					
1056	Manganese (ug/l)										
38260	MBAS (mg/l)	0	0								
71890	Mercury (ug/l)	0.10	0.10			1					
1060	Molybdenum (ug/l)										
1065	Nickel (ug/l)										
71851	Nitrate (NO_3) (mg/l)										
71856	Nitrite (NO_2^-) (mg/l)										
631	Nitrite Plus Nitrate (N) (mg/l)	0.72	0.61	0.66	1.12	2					
608	Nitrogen, Ammonia (mg/l)	0.09	0.05	0.07	1.52	2					
607	Nitrogen, Organic (mg/l)										
1330	Odor (Severity)										
550	Oil & Grease (mg/l)										
	Organic Carbon (mg/l)										
681	Dissolved	67.0	34.0	47.73	1.62	2					
689	Suspended	<10.0	3.90	6.24	1.95	2					
680	Total										
	Pesticides (ug/l)										
400	pH*	8.50	8.40	8.45	0.07	2					
32730	Phenols (ug/l)										
	Phosphate (mg/l)										
660	Dissolved (PO_4)	0.25	0.09	0.15	2.06	2					
671	Ortho (P)	0.08	0.03	0.05	2.00	2					
665	Total (P)	2.50	0.70	1.32	2.46	2					
935	Potassium (mg/l)	2.90	2.30	2.58	1.18	2					
	Radioactivity										
	Gross Alpha (pc/l)										
9511	Radium 226 (pc/l)										
80030	Natural Uranium (ug/l)										
	Gross Beta (pc/l)										
80050	Sr^{90} (pc/l)										
3515	Cs^{137} (pc/l)										
1145	Selenium (ug/l)	<1.00	<1.00			1					
955	Silica (SiO_2) (mg/l)	5.80	5.00	5.39	1.11	2					
1075	Silver (ug/l)										
930	Sodium (mg/l)	24.00	16.00	19.60	1.33	2					
931	Sodium Adsorption Ratio	1.70	0.90	1.24	1.57	2					
70301	Solids, Dissolved (mg/l)	102.00	98.00	99.98	1.03	2					
1080	Stronium (ug/l)	100.00	100.00			1					
945.	Sulfate (mg/l)	6.80	5.30	6.00	1.19	2					
746	Sulfide (mg/l)										
10	Temperature (°C)*	8.00	1.00	4.50	4.95	2					
1100	Tin (ug/l)										
1150	Titanium (ug/l)										
70	Turbidity (JTU)										
1085	Vanadium (ug/l)										
1090	Zinc (ug/l)	90.00	90.00			1					
1160	Zirconium (ug/l)										

* Normal mean and standard deviation

TABLE 2.11

BASELINE SURFACE WATER QUALITY SUMMARY
STAKE SPRINGS NEAR CONFLUENCE WITH CORRAL GULCH

Param. No.	Item	USGS DATA High	Low	Geo. Mean	Geo. Dev.	No. of Analy.	NUS DATA High	Low	Geo. Mean	Geo. Dev.	No. of Analy.
410	Alkalinity (mg/l)	114.00	114.00			1					
1106	Aluminum (ug/l)	100.00	100.00			1					
71846	Ammonia (NH_3) (mg/l)	0.14	0.14			1					
1000	Arsenic (ug/l)	2.00	2.00			1					
1005	Barium (ug/l)										
1010	Beryllium (ug/l)										
440	Bicarbonate (mg/l)	139.00	139.00			1					
1015	Bismuth (ug/l)										
310	BOD (mg/l)										
1020	Boron (ug/l)	160.00	160.00			1					
71870	Bromide (mg/l)										
1025	Cadmium (ug/l)										
915	Calcium (mg/l)	26.00	26.00			1					
445	Carbonate (mg/l)	0	0			1					
940	Chloride (mg/l)	4.20	4.20			1					
1030	Chromium (ug/l)										
340	COD (mg/l)										
31616	Coliform, Fecal (Col/100 ml)										
74050	Coliform, Total (Col/100 ml)										
80	Color (PCU)	100.0	100.0			1					
95	Conductivity, Spec. (umhos)	280.00	280.00			1					
1040	Copper (ug/l)										
720	Cyanide (mg/l)										
300	Dissolved Oxygen (mg/l)										
950	Fluoride (mg/l)	0.10	0.10			1					
1120	Gallium (ug/l)										
1125	Germanium(ug/l)										
900	Hardness (Ca,Mg) (mg/l)	94.00	94.00			1					
1046	Iron (ug/l)	180.00	180.00			1					
625	Kjeldahl Nitrogen (mg/l)										
1049	Lead (ug/l)										
1130	Lithium (ug/l)										
925	Magnesium (mg/l)	6.90	6.90			1					
1056	Manganese (ug/l)										
38260	MBAS (mg/l)										
71890	Mercury (ug/l)										
1060	Molybdenum (ug/l)										
1065	Nickel (ug/l)										
71851	Nitrate (NO_3) (mg/l)										
71856	Nitrite (NO_2) (mg/l)										
631	Nitrite Plus Nitrate (N) (mg/l)	0.42	0.42			1					
608	Nitrogen, Ammonia (mg/l)	0.11	0.11			1					
607	Nitrogen, Organic (mg/l)	2.30	2.30			1					
1330	Odor (Severity)	0	0			1					
550	Oil & Grease (mg/l)										
	Organic Carbon (mg/l)										
681	Dissolved	67.0	67.0			1					
689	Suspended	1.4	1.4			1					
680	Total										
	Pesticides (ug/l)										
400	pH*	8.40	8.40			1					
32730	Phenols (ug/l)										
	Phosphate (mg/l)										
660	Dissolved (PO_4)	0.49	0.49			1					
671	Ortho (P)	0.16	0.16			1					
665	Total (P)	0.34	0.34			1					
935	Potassium (mg/l)	5.40	5.40			1					
	Radioactivity										
	Gross Alpha (pc/l)										
9511	Radium 226 (pc/l)										
80030	Natural Uranium (ug/l)										
	Gross Beta (pc/l)										
80050	Sr^{90} (pc/l)										
3515	Cs^{137} (pc/l)										
1145	Selenium (ug/l)										
955	Silica (SiO_2) (mg/l)	5.30	5.30			1					
1075	Silver (ug/l)										
930	Sodium (mg/l)	17.00	17.00			1					
931	Sodium Adsorption Ratio	0.80	0.80			1					
70301	Solids, Dissolved (mg/l)	154.00	154.00			1					
1080	Strontium (ug/l)	390.00	390.00			1					
945	Sulfate (mg/l)	17.00	17.00			1					
746	Sulfide (mg/l)										
10	Temperature (°C)*	3.00	3.00			1					
1100	Tin (ug/l)										
1150	Titanium (ug/l)										
70	Turbidity (JTU)										
1085	Vanadium (ug/l)										
1090	Zinc (ug/l)										
1160	Zirconium (ug/l)										

* Normal mean and standard deviation

TABLE 2.12

BASELINE SURFACE WATER QUALITY SUMMARY
BOX ELDER GULCH NEAR WEST LINE TRACT C-a

Param. No.	Item	USGS DATA High	Low	Geo. Mean	Geo. Dev.	No. of Analy.	NUS DATA High	Low	Geo. Mean	Geo. Dev.	No. of Analy.
410	Alkalinity (mg/l)	372.00	74.00	283.00	1.15	12					
1106	Aluminum (ug/l)	130.00	30.00	57.48	1.91	4					
71846	Ammonia (NH_3) (mg/l)	0.32	0.01	0.02	3.71	7	<0.10	<0.10	<0.10	1.00	4
1000	Arsenic (ug/l)	15.00	3.00	6.01	1.74	8					
1005	Barium (ug/l)	200.00	<50.00	74.76	1.57	10					
1010	Beryllium (ug/l)	<5.00	<1.00	<2.51	2.07	4					
440	Bicarbonate (mg/l)	453.00	90.00	338.83	1.15	12					
1015	Bismuth (ug/l)	<15.00	<4.00	<6.62	1.89	4					
310	BOD (mg/l)	1.0	1.0	--	--	1					
1020	Boron (ug/l)	110.00	50.00	75.58	1.32	11					
71870	Bromide (mg/l)	0	0	--	--	1					
1025	Cadmium (ug/l)	<10.00	1.00	4.27	3.06	10					
915	Calcium (mg/l)	86.00	17.00	66.35	1.22	12	80.00	60.00	68.46	1.16	4
445	Carbonate (mg/l)	0	0	0		12					
940	Chloride (mg/l)	8.20	3.00	5.57	1.08	12	6.00	5.40	5.79	1.05	4
1030	Chromium (ug/l)	20.00	<1.00	3.24	3.10	8					
340	COD (mg/l)	100.00	6.00	23.63	4.09	3					
31616	Coliform, Fecal (Col/100 ml)	200.00	200.00	--	--	1					
74050	Coliform, Total (Col/100 ml)	710	710	--	--	1					
80	Color (PCU)	100	2	11.27	3.23	7	35.0	2.50	9.35	4.59	4
95	Conductivity, Spec. (umhos)	1,160.00	400.00	845.16	1.09	12					
1040	Copper (ug/l)	22.00	1.00	2.99	3.12	10					
720	Cyanide (mg/l)	0.01	0.01	0.01	1.00	6					
300	Dissolved Oxygen (mg/l)	9.80	5.50	7.83	1.14	10					
950	Fluoride (mg/l)	0.70	0.10	0.33	1.58	12					
1120	Gallium (ug/l)	<5.00	<1.00	< 2.66	2.19	4					
1125	Germanium(ug/l)	<20.00	<3.00	<7.40	2.28	4					
900	Hardness (Ca,Mg) (mg/l)	460.00	65.00	313.20	1.66	12	410.00	250.00	333.02	1.27	4
1046	Iron (ug/l)	500.00	8.00	18.50	2.54	12					
625	Kjeldahl Nitrogen (mg/l)	2.70	0.31	.67	2.67	4					
1049	Lead (ug/l)	11.00	1.00	3.25	2.67	10					
1130	Lithium (ug/l)	20.00	<5.00	14.52	2.12	10					
925	Magnesium (mg/l)	61.00	5.40	39.43	1.88	12	44.00	41.00	42.47	1.04	4
1056	Manganese (ug/l)	30.00	<4.00	9.86	1.84	12					
38260	MBAS (mg/l)	--	--			--					
71890	Mercury (ug/l)	0.20	<0.01	0.01	2.88	8					
1060	Molybdenum (ug/l)	40.00	3.00	19.58	3.50	4					
1065	Nickel (ug/l)	<10.00	<3.00	<4.95	1.67	4					
71851	Nitrate (NO_3) (mg/l)	4.40	3.90	4.12	1.05	4	1.10	0.40	0.72	1.60	4
71856	Nitrite (NO_2) (mg/l)	0.03	<0.01	0.02	1.89	4	<0.10	<0.01	<0.02	3.16	4
631	Nitrite Plus Nitrate (N) (mg/l)	1.50	0.23	1.06	1.53	12					
608	Nitrogen, Ammonia (mg/l)	0.25	0.01	0.02	3.38	7					
607	Nitrogen, Organic (mg/l)	30.0	0.28	1.51	13.40	3					
1330	Odor (Severity)	0	0	0	1.00	12	0	0	0	1.0	4
550	Oil & Grease (mg/l)	11.00	1.00	2.53	2.23	6					
	Organic Carbon (mg/l)										
681	Dissolved	34.00	4.20	9.67	2.45	4					
689	Suspended	2.40	.70	1.30	2.39	2					
680	Total	11.0	11.0	--	--	1					
	Pesticides (ug/l)	0	0	0	1.0	2					
400	pH*	9.00	7.70	8.04	0.27	11					
32730	Phenols (ug/l)	3.0	3.0	--	--	1					
	Phosphate (mg/l)										
660	Dissolved (PO_4)	1.10	<0.01	0.05	1.62	12	<0.01	<0.01	<0.01	1.00	4
671	Ortho (P)	0.35	<0.01	0.02	2.71	12					
665	Total (P)	0.83	0.01	.11	5.54	7	0.67	0.12	0.28	2.54	4
935	Potassium (mg/l)	11.00	0.70	1.21	2.09	12	1.60	1.10	1.31	1.22	4
	Radioactivity										
	Gross Alpha (pc/l) #	7.48	1.56	3.42	3.02	2					
9511	Radium 226 (pc/l)	--	--	--	--	--					
80030	Natural Uranium (ug/l)	11.00	2.30	5.03	3.02	2					
	Gross Beta (pc/l)										
80050	SR^{90} (pc/l)	13.00	4.80	7.90	2.02	2					
3515	CE^{137} (pc/l)	16.00	5.80	9.63	2.05	2					
1145	Selenium (ug/l)	6.00	<1.00	3.54	1.69	9					
955	Silica (SiO_2) (mg/l)	24.00	3.20	19.28	1.76	12	22.47	20.54	21.33	1.04	4
1075	Silver (ug/l)	<2.00	<1.00	<1.19	1.41	4					
930	Sodium (mg/l)	93.00	2.70	42.90	2.45	12	51.00	48.00	49.73	1.03	4
931	Sodium Adsorption Ratio	1.90	0.10	1.03	2.13	12					
70301	Solids, Dissolved (mg/l)	777.00	96.00	468.27	1.68	12	506.00	469.00	492.04	1.03	4
1080	Strontium (ug/l)	1,000.00	200.00	599.07	2.11	4					
945	Sulfate (mg/l)	280.00	5.50	125.57	2.72	12	137.74	131.75	134.73	1.02	4
746	Sulfide (mg/l)	1.10	<0.01	0.10	6.60	6					
10	Temperature (°C)*	27.50	3.00	13.97	7.67	13					
1100	Tin (ug/l)	<10.00	<4.00	<6.32	1.52	4					
1150	Titanium (ug/l)	<7.00	<1.00	<2.89	2.42	4					
70	Turbidity (JTU)	210.00	13.00	45.72	3.19	4	220.00	60.00	115.86	2.04	4
1085	Vanadium (ug/l)	<10.00	<3.00	<5.48	1.64	4					
1090	Zinc (ug/l)	65.00	10.00	14.85	2.00	10					
1160	Zirconium (ug/l)	<20.00	<5.00	<9.46	2.10	4					

* Normal mean and standard deviation # Calculated from Gross Alpha as Natural Uranium

TABLE 2.13

BASELINE SURFACE WATER QUALITY SUMMARY
CORRAL GULCH NEAR WEST LINE TRACT C-a

Param. No.	Item	USGS Data High	Low	Geo. Mean	Geo. Dev.	No.of Analy	NUS DATA High	Low	Geo. Mean	Geo. Dev.	No.of Analy.
410	Alkalinity (mg/l)	421.00	267.00	318.26	1.06	45					
1106	Aluminum (ug/l)	220.00	20.00	39.49	2.12	8					
71846	Ammonia (NH_3) (mg/l)	0.12	0.01	0.02	2.47	20	<0.10	<0.10	< 0.10	1.00	22
1000	Arsenic (ug/l)	23.00	1.00	4.40	1.29	39					
1005	Barium (ug/l)	200.00	< 50.00	78.17	2.14	38					
1010	Beryllium (ug/l)	< 6.00	< 1.00	< 2.67	1.94	6					
440	Bicarbonate (mg/l)	513.00	325.00	387.57	1.06	45					
1015	Bismuth (ug/l)	<20.00	< 5.00	< 8.49	1.86	6					
310	BOD (mg/l)	2.68	0.70	1.14	2.10	3					
1020	Boron (ug/l)	130.00	30.00	96.10	1.18	43					
71870	Bromide (mg/l)	0.10	0.10	0.10	1.0	2					
1025	Cadmium (ug/l)	<10.00	1.00	3.64	2.84	41					
915	Calcium (mg/l)	99.00	58.00	87.76	1.08	46	94.00	65.00	79.10	1.13	22
445	Carbonate (mg/l)	0	0	0	1.00	36					
940	Chloride (mg/l)	12.00	5.70	7.61	1.15	46	12.00	5.80	7.24	1.12	22
1030	Chromium (ug/l)	<15.00	< 1.00	< 2.27	2.89	20					
340	COD (mg/l)	21.00	5.00	13.22	1.80	5					
31616	Coliform, Fecal (Col/100 ml)	<10.0	<10.0	--	--	1					
74050	Coliform, Total (Col/100 ml)	96.0	96.0	--	--	1					
80	Color (PCU)	25.0	3.0	5.65	1.99	20	35.0	2.50	9.51	1.46	22
95	Conductivity, Spec. (umhos)	1200.00	900.00	1079.71	1.05	46					
1040	Copper (ug/l)	14.00	1.00	2.60	2.59	39					
720	Cyanide (mg/l)	< 0.01	< 0.01	< 0.01	1.00	16					
300	Dissolved Oxygen (mg/l)	11.70	5.60	8.74	1.20	38					
950	Fluoride (mg/l)	1.50	< 0.10	0.25	1.52	46	0.30	0.30	0.30	1.00	2
1120	Gallium (ug/l)	< 7.00	< 2.00	< 3.90	1.83	6					
1125	Germanium(ug/l)	<40.00	< 5.00	<11.83	2.19	6					
900	Hardness (Ca,Mg) (mg/l)	510.00	390.00	460.36	1.05	46	470.00	361.00	422.81	1.10	22
1046	Iron (ug/l)	280.00	<10.00	43.24	2.74	46	<20.00	<20.00	<20.00	1.00	2
625	Kjeldahl Nitrogen (mg/l)	4.20	0.25	0.48	1.69	13					
1049	Lead (ug/l)	230.00	< 1.00	2.56	2.54	39					
1130	Lithium (ug/l)	20.00	< 5.00	12.26	1.81	39					
925	Magnesium (mg/l)	70.00	50.00	58.58	1.05	46	64.00	45.00	58.43	1.06	22
1056	Manganese (ug/l)	160.00	< 2.00	11.57	1.92	44					
38260	MBAS (mg/l)	4.0	4.0	--	--	1					
71890	Mercury (ug/l)	1.20	< 0.01	0.02	3.97	36					
1060	Molybdenum (ug/l)	50.00	23.00	37.99	1.32	7					
1065	Nickel (ug/l)	<15.00	< 5.00	< 7.63	1.72	6					
71851	Nitrate (NO_3) (mg/l)	6.60	1.20	4.01	1.18	13	1.60	<0.20	0.55	1.97	22
71856	Nitrite (NO_2) (mg/l)	0.03	< 0.01	0.02	1.74	13	< 0.01	< 0.01	< 0.01	1.00	22
631	Nitrite Plus Nitrate (N) (mg/l)	2.20	0.01	0.92	1.59	46					
608	Nitrogen, Ammonia (mg/l)	0.09	0.01	0.02	2.17	20					
607	Nitrogen, Organic (mg/l)	0.79	0.35	0.49	1.33	7					
1330	Odor (Severity)	1.0	0.0	0.0	4.43	42	0	0	0	1.0	22
550	Oil & Grease (mg/l)	9.00	< 0.10	0.82	5.41	15					
	Organic Carbon (mg/l)										
681	Dissolved	16.0	4.60	9.52	1.50	8	26.0	<1	6.68	2.59	44
689	Suspended	2.50	< 0.10	.67	3.47	6					
680	Total	44.0	8.0	17.79	2.36	3					
	Pesticides (ug/l)	0	0	0	1.0	3					
400	pH*	8.70	7.30	8.09	0.26	44					
32730	Phenols (ug/l)	3.0	1.0	1.73	2.17	2					
	Phosphate (mg/l)										
660	Dissolved (PO_4)	0.28	< 0.01	0.02	2.78	46	0.02	< 0.01	0.01	1.16	22
671	Ortho (P)	0.09	0.01	0.01	1.71	46					
665	Total (P)	1.30	0.01	0.04	3.85	20	1.00	0.02	0.06	2.12	22
935	Potassium (mg/l)	2.80	0.60	1.39	1.35	46	2.70	1.50	1.97	1.29	22
	Radioactivity										
	Gross Alpha (pc/l)#	<9.52	< 6.05	<7.06	1.23	4					
9511	Radium 226 (pc/l)	0.11	0.08	0.09	1.25	2					
80030	Natural Uranium (ug/l)	<14.00	< 8.90	< 10.38	1.23	4					
	Gross Beta (pc/l)										
80050	SR^{90} (pc/l)	26.00	2.80	6.46	2.63	4					
3515	CE^{137} (pc/l)	33.00	3.50	7.99	2.66	4					
1145	Selenium (ug/l	8.00	1.00	3.77	1.23	37					
955	Silica (SiO_2) (mg/l)	24.00	0.00	18.78	2.00	46	21.83	18.19	19.75	1.08	22
1075	Silver (ug/l)	< 2.00	< 1.00	< 1.41	1.46	6					
930	Sodium (mg/l)	120.00	49.00	84.86	1.12	46	92.00	72.00	89.25	1.03	22
931	Sodium Absorption Ratio	2.30	1.00	1.81	1.08	46					
70301	Solids, Dissolved (mg/l)	874.00	663.00	739.52	1.03	45	749.00	643.00	715.73	1.03	22
1080	Strontium (ug/l)	2000.00	1200.00	1503.15	1.20	8					
945	Sulfate (mg/l)	320.00	240.00	282.92	1.06	46	272.49	212.60	259.60	1.03	22
746	Sulfide (mg/l)	0.60	< 0.01	0.05	5.34	16					
10	Temperature (0c)*	30.00	0.50	14.59	7.38	50					
1100	Tin (ug/l)	< 15.00	< 5.00	< 9.06	1.57	6					
1150	Titanium (ug/l)	< 10.00	< 3.00	< 5.38	1.90	6					
70	Turbidity (JTU)	450.00	2.00	27.58	2.47	13	450.00	2.00	20.51	4.54	22
1085	Vanadium (ug/l)	< 15.00	< 3.00	< 7.86	1.89	6					
1090	Zinc (ug/l)	410.00	6.00	15.14	2.58	39					
1160	Zirconium (ug/l)	< 40.00	< 7.00	<15.08	2.13	6					

* Normal mean and standard deviation # Calculated from Gross Alpha as Natural Uranium

TABLE 2.14

BASELINE SURFACE WATER QUALITY SUMMARY
CORRAL GULCH EAST OF TRACT C-a

Param. No.	Item	USGS Data High	Low	Geo. Mean	Geo. Dev.	No.of Analy.	NUS DATA High	Low	Geo. Mean	Geo. Dev.	No.of Analy
410	Alkalinity (mg/l)	739.00	268.00	403.86	1.08	58					
1106	Aluminum (ug/l)	100.00	10.00	24.28	2.12	11					
71846	Ammonia (NH_4) (mg/l)	0.35	0.01	0.03	3.07	30	< 0.10	< 0.01	< 0.09	1.60	24
1000	Arsenic (ug/l)	14.00	1.00	5.33	1.29	50					
1005	Barium (ug/l)	< 200.00	< 50.00	< 74.09	1.81	45					
1010	Beryllium (ug/l)	< 7.00	< 2.00	< 3.32	1.67	7					
440	Bicarbonate (mg/l)	901.00	327.00	492.00	1.08	58					
1015	Bismuth (ug/l)	< 25.00	< 5.00	< 10.38	1.92	7					
310	BOD (mg/l)	2.60	2.00	2.25	1.14	3					
1020	Boron (ug/l)	670.00	60.00	116.78	1.22	53					
71870	Bromide (mg/l)	0.10	0.10	0.10	1.0	3					
1025	Cadmium (ug/l)	< 60.00	1.00	3.39	3.33	48					
915	Calcium (mg/l)	110.00	55.00	85.56	1.07	58	88.00	54.00	78.91	1.13	24
445	Carbonate (mg/l)	0	0	0	1.00	49					
940	Chloride (mg/l)	19.00	5.90	9.78	1.18	58	25.00	8.00	10.41	1.25	24
1030	Chromium (ug/l)	50.00	< 1.00	2.79	3.51	27					
340	COD (mg/l)	94.00	5.00	13.61	2.60	8					
31616	Coliform, Fecal (Col/100 ml)	220.00	0	2.07	89.66	6					
74050	Coliform, Total (Col/100 ml)	580.00	180.00	323.11	2.29	2					
80	Color (PCU)	17.00	0	4.51	2.22	32	25.00	2.50	10.52	2.41	24
95	Conductivity, Spec. (umhos)	1725.00	797.00	1231.54	1.07	59					
1040	Copper (ug/l)	13.00	1.00	2.15	3.02	46					
720	Cyanide (mg/l)	0.02	< 0.01	0.01	1.21	25					
300	Dissolved Oxygen (mg/l)	13.00	4.80	8.32	1.25	53					
950	Fluoride (mg/l)	10.00	0.20	0.49	2.02	58	0.40	0.40	0.40	1.00	4
1120	Gallium (ug/l)	< 8.00	< 2.00	< 4.58	1.73	7					
1125	Germanium(ug/l)	< 40.00	< 6.00	< 12.39	2.13	7					
900	Hardness (Ca,Mg) (mg/l)	520.00	360.00	476.06	1.08	58	508.00	358.00	446.00	1.10	24
1046	Iron (ug/l)	240.00	10.00	31.25	2.35	55	<20.00	<20.00	<20.00	1.00	4
625	Kjeldahl Nitrogen (mg/l)	2.40	0.14	0.42	2.09	21					
1049	Lead (ug/l)	18.00	< 1.00	1.90	2.09	46					
1130	Lithium (ug/l)	40.00	< 5.00	11.59	2.35	46					
925	Magnesium (mg/l)	71.00	45.00	62.04	1.10	58	80.00	43.00	59.90	1.17	24
1056	Manganese (ug/l)	70.00	5.00	16.83	1.99	52					
38260	MBAS (mg/l)	3.00	0.10	.55	11.08	2					
71890	Mercury (ug/l)	1.30	< 0.01	0.02	3.50	46					
1060	Molybdenum (ug/l)	56.00	23.00	37.55	1.40	8					
1065	Nickel (ug/l)	< 20.00	< 4.00	< 8.59	1.92	7					
71851	Nitrate (NO_3) (mg/l)	3.00	0.93	1.22	1.14	20	1.00	0.20	0.28	1.75	24
71856	Nitrite (NO_2^-) (mg/l)	0.10	< 0.01	0.02	2.86	21	0.02	< 0.01	0.01	1.15	24
631	Nitrite Plus Nitrate (N) (mg/l)	2.00	0.02	0.32	1.59	58					
608	Nitrogen, Ammonia (mg/l)	0.27	0.01	0.03	2.76	31					
607	Nitrogen, Organic (mg/l)	0.89	0.07	0.29	1.99	9					
1330	Odor (Severity)	3.00	0	0	8.31	57	0	0	0	1.0	24
550	Oil & Grease (mg/l)	16.00	< 0.10	2.90	3.04	24					
	Organic Carbon (mg/l)										
681	Dissolved	14.00	1.70	8.12	1.73	10	91.00	< 1.00	12.41	2.52	48
689	Suspended	8.70	0.30	0.36	1.40	10					
680	Total	15.00	9.80	11.37	1.27	3					
	Pesticides (ug/l)	0	0	0	1.00	6					
400	pH*	8.90	7.10	7.88	0.31	58					
32730	Phenols (ug/l)	3.00	0	0.05	287.50	2					
	Phosphate (mg/l)										
660	Dissolved (PO_4)	0.40	< 0.01	0.06	2.11	58	0.04	0.01	0.03	1.46	24
671	Ortho (P)	0.13	< 0.01	0.02	2.06	58					
665	Total (P)	0.06	0.01	0.03	2.02	31	2.10	0.03	0.04	1.55	24
935	Potassium (mg/l)	3.00	0.70	1.59	1.22	58	4.40	1.70	2.18	1.19	24
	Radioactivity										
	Gross Alpha (pc/l) #	<8.84	<4.56	< 6.60	1.29	7					
9511	Radium 226 (pc/l)	0.10	0.05	0.07	1.34	4					
80030	Natural Uranium (ug/l)	< 13.00	< 6.70	< 9.70	1.29	7					
	Gross Beta (pc/l)										
80050	Sr^{90} (pc/l)	7.50	2.00	3.10	1.59	7					
3515	Cs^{137} (pc/l)	9.40	2.40	3.83	1.61	7					
1145	Selenium (ug/l	8.00	1.00	2.96	1.39	45					
955	Silica (SiO_2) (mg/l)	24.00	13.00	21.10	1.07	58	21.83	9.20	18.28	1.30	24
1075	Silver (ug/l)	< 2.00	< 1.00	< 1.49	1.45	7					
930	Sodium (mg/l)	300.00	51.00	109.15	1.10	58	350.00	91.00	108.98	1.15	24
931	Sodium Adsorption Ratio	6.80	1.20	2.15	1.10	58					
70301	Solids, Dissolved (mg/l)	1140.00	522.00	822.87	1.07	57	1200.00	691.00	810.23	1.06	24
1080	Strontium (ug/l)	2000.00	1300.00	1686.55	1.15	11					
945	Sulfate (mg/l)	360.00	160.00	288.77	1.10	58	299.44	179.66	259.62	1.10	24
746	Sulfide (mg/l)	0.80	< 0.01	0.06	5.17	25					
10	Temperature (°C)*	22.00	3.00	11.47	4.12	65					
1100	Tin (ug/l)	< 20.00	< 5.00	< 9.65	1.75	7					
1150	Titanium (ug/l)	< 10.00	< 3.00	< 6.02	1.67	7					
70	Turbidity (JTU)	1000.00	1.0	8.23	8.94	21	1000.00	0.30	1.79	5.41	24
1085	Vanadium (ug/l)	< 16.00	3.00	6.83	1.97	7					
1090	Zinc (ug/l)	100.00	4.00	12.47	2.05	46					
1160	Zirconium (ug/l)	< 40.00	< 9.00	< 18.35	1.86	7					

* Normal mean and standard deviation # Calculated from Gross Alpha as Natural Uranium

TABLE 2.15

BASELINE SURFACE WATER QUALITY SUMMARY YELLOW CREEK NEAR WHITE RIVER

Param. No.	Item	USGS Data High	Low	Geo. Mean	Geo. Dev.	No. of Analy.	NUS Data High	Low	Geo. Mean	Geo. Dev.	No. of Analy.
410	Alkalinity (mg/l)	1670.00	894.00	1443.10	1.12	43					
1106	Aluminum (ug/l)	150.00	<10.00	75.44	1.51	11					
71846	Ammonia (NH_4) (mg/l)	0.52	<0.01	0.03	8.54	34	0.17	<0.10	0.10	1.14	24
1000	Arsenic (ug/l)	10.00	<0.01	3.81	3.05	36					
1005	Barium (ug/l)	400.00	<50.00	165.13	1.82	35					
1010	Beryllium (ug/l)	<20.00	<4.00	<7.22	1.86	7					
440	Bicarbonate (mg/l)	1990.00	596.00	1513.94	1.19	43					
1015	Bismuth (ug/l)	<70.00	<15.00	<30.58	1.99	7					
310	BOD (mg/l)	5.80	1.00	1.93	2.20	4					
1020	Boron (ug/l)	880.00	230.00	691.87	1.15	43					
71870	Bromide (mg/l)	0.70	0.20	0.35	1.90	3					
1025	Cadmium (ug/l)	<170.00	1.00	3.08	4.00	36					
915	Calcium (mg/l)	130.00	7.00	31.81	1.43	45	96.00	12.00	23.73	1.72	24
445	Carbonate (mg/l)	657.00	<1.00	49.58	8.34	43					
940	Chloride (mg/l)	200.00	93.00	125.91	1.15	45	179.00	96.00	137.58	1.23	24
1030	Chromium (ug/l)	80.00	<1.00	2.77	4.53	29					
340	COD (mg/l)	60.00	7.00	20.30	1.85	8					
31616	Coliform, Fecal (Col/100 ml)	1,400.00	0	66.84	102.73	8					
74050	Coliform, Total (Col/100 ml)	620.00	620.00	--	--	1					
80	Color (PCU)	80.00	2.00	11.87*	2.41	34	35.00	2.50	21.34	2.03	24
95	Conductivity, Spec. (umhos)	5000.00	2410.00	3689.72	1.07	45					
1040	Copper (ug/l)	<10.00	<1.00	<3.12	2.15	36					
720	Cyanide (mg/l)	<0.01	<0.01	<0.01	1.00	26					
300	Dissolved Oxygen (mg/l)	12.60	5.60	9.59	1.27	41					
950	Fluoride (mg/l)	3.00	1.20	2.26	1.17	44	0.46	<0.10	0.21	2.35	4
1120	Gallium (ug/l)	<20.00	<5.00	<10.36	1.66	7					
1125	Germanium(ug/l)	<70.00	<20.00	<33.85	1.81	7					
900	Hardness (Ca,Mg) (mg/l)	670.00	420.00	530.16	1.12	45	590.00	422.00	483.08	1.12	24
1046	Iron (ug/l)	660.00	<8.00	25.64	2.38	43	<20.00	<20.00	<20.00	1.00	4
625	Kjeldahl Nitrogen (mg/l)	2.60	0.17	0.75	1.56	22					
1049	Lead (ug/l)	<50.00	1.00	2.14	3.02	36					
1130	Lithium (ug/l)	180.00	80.00	151.42	1.18	36					
925	Magnesium (mg/l)	140.00	50.00	108.24	1.16	45	130.00	9.60	87.43	1.98	24
1056	Manganese (ug/l)	250.00	10.00	12.25	1.53	40					
38260	MBAS (mg/l)	2.00	0.30	0.77	3.82	2					
71890	Mercury (ug/l)	0.90	<0.01	0.02	3.31	34					
1060	Molybdenum (ug/l)	80.00	16.00	38.33	1.94	8					
1065	Nickel (ug/l)	<50.00	<10.00	<24.78	1.93	7					
71851	Nitrate (NO_3) (mg/l)	12.00	0.04	4.80	2.93	22	2.30	<0.20	0.40	2.54	24
71856	Nitrite (NO_2) (mg/l)	0.23	<0.01	0.05	2.36	22	0.01	0.01	0.01	1.00	24
631	Nitrite Plus Nitrate (N) (mg/l)	2.70	0.01	0.41	5.54	45					
608	Nitrogen, Ammonia (mg/l)	0.40	<0.01	0.04	4.17	34					
607	Nitrogen, Organic (mg/l)	0.99	0.31	0.57	1.53	10					
1330	Odor (Severity)	3.00	0	0	7.35	43	0	0	0	1.0	24
550	Oil & Grease (mg/l)	17.00	<0.10	0.66	5.91	24					
	Organic Carbon (mg/l)										
681	Dissolved	43.00	4.30	8.97	1.68	12	230.00	<1.0	29.64	6.42	48
689	Suspended	2.40	0.02	0.78	2.24	8					
680	Total	29.00	4.70	11.20	2.21	4					
	Pesticides (ug/l)	0	0	0	1.0	6					
400	pH#	10.10	8.00	8.55	0.20	44					
32730	Phenols (ug/l)	1.00	0	0.03	132.23	2					
	Phosphate (mg/l)										
660	Dissolved (PO_4)	5.50	<0.01	0.06	4.20	45	0.05	<0.01	0.01	1.58	24
671	Ortho (P)	1.80	0.01	0.03	3.06	45					
665	Total (P)	0.79	0.01	0.07	3.71	33	0.23	0.01	0.03	2.07	24
935	Potassium (mg/l)	7.40	3.50	4.14	1.17	45	7.40	5.00	6.54	1.07	24
	Radioactivity										
	Gross Alpha (pc/l)#	46.24	<16.32	24.53	1.51	6					
9511	Radium 226 (pc/l)	0.12	0.12			1					
80030	Natural Uranium (ug/l)	68.00	<24.00	36.07	1.51	6					
	Gross Beta (pc/l)										
80050	Sr^{90} (pc/l)	36.00	<6.20	11.76	1.86	6					
3515	Cs^{137} (pc/l)	45.00	<7.70	13.97	1.90	6					
1145	Selenium (ug/l)	3.00	<1.00	1.90	1.53	34					
955	Silica (SiO_2) (mg/l)	20.00	0.30	10.34	1.68	45	16.05	0.09	8.66	1.62	24
1075	Silver (ug/l)	<5.00	<2.00	<2.96	1.63	7					
930	Sodium (mg/l)	940.00	500.00	778.28	1.12	45	920.00	640.00	824.39	1.10	24
931	Sodium Adsorption Ratio	19.00	9.40	14.53	1.15	45					
70301	Solids, Dissolved (mg/l)	2870.00	1740.00	2512.67	1.08	43	2780.99	2099.99	2492.88	1.09	24
1080	Strontium (ug/l)	3600.00	2700.00	3222.30	1.10	11					
945	Sulfate (mg/l)	750.00	400.00	556.14	1.11	45	1410.36	404.24	532.64	1.12	24
746	Sulfide (mg/l)	0.60	<0.01	0.05	4.80	27					
10	Temperature (°C)#	28.00	0	12.29	11.02	45					
1100	Tin (ug/l)	<50.00	<15.00	<27.77	1.75	7					
1150	Titanium (ug/l)	<30.00	<8.00	<15.02	1.73	7					
70	Turbidity (JTU)	400.00	3.00	48.45	5.76	23	110.00	3.00	22.55	3.16	24
1085	Vanadium (ug/l)	<50.00	<8.00	<20.06	2.12	7					
1090	Zinc (ug/l)	140.00	2.00	12.72	2.08	36					
1160	Zirconium (ug/l)	<100.00	<25.00	<49.99	1.95	7					

* Normal mean and standard deviation. # Calculated from Gross Alpha as Natural Uranium.

TABLE 2.16

BASELINE SURFACE WATER QUALITY SUMMARY
SELECTED WHITE RIVER STATIONS, OCTOBER 1974-OCTOBER 1976

Parameter	NUS Station 23 High	Low	Geo. Mean	Geo. Dev.	No. of Analy.	NUS Station 28 High	Low	Geo. Mean	Geo. Dev.	No of Analy.
Ammonia (mg/l)	0.14	<0.10	0.10	1.07	24	<0.10	<0.10	<0.10	1.00	24
Calcium (mg/l)	84.00	37.00	71.58	1.14	24	88.00	35.00	68.08	1.14	24
Carbon Organic Dissolved (mg/l)	17.00	1.00	6.52	2.33	48	25.00	<1.00	7.28	2.01	48
Chloride (mg/l)	44.00	8.00	29.95	1.35	24	43.00	12.00	34.55	1.21	24
Color (PCU)	35.00	2.50	10.21	3.25	24	25.00	2.50	8.39	3.28	24
Fluoride (mg/l)	0.30	<0.10	0.17	1.83	4	0.25	<0.10	0.15	1.66	4
Hardness (mg/l as $CaCO_3$)	334.00	160.00	263.30	1.23	24	368.00	160.00	265.63	1.11	24
Iron Dissolved (µg/l)	<0.02	<0.02	<0.02	1.00	4	<0.02	<0.02	<0.02	1.00	4
Iron Total (µg/l)	1.70	0.18	0.67	3.06	4	2.10	0.22	0.64	3.42	4
Magnesium (mg/l)	36.00	10.00	23.75	1.41	24	37.00	13.00	25.97	1.36	24
Nitrate (mg/l)	1.00	<0.20	0.23	1.55	24	<0.20	<0.20	<0.20	1.00	24
Nitrite (mg/l)	<0.01	<0.01	<0.01	1.00	24	<0.01	<0.01	<0.01	1.00	24
Nitrogen (mg/l)	0.98	0.12	0.32	1.71	24	1.50	<0.10	0.26	2.17	24
Odor (Severity)	0.00	0.00	0.00	1.00	24	0.00	0.00	0.00	1.00	24
Phosphorous Ortho (mg/l)	0.02	0.01	0.01	1.41	24	0.04	0.01	0.01	1.64	24
Phosphorous Total (mg/l)	0.27	0.02	0.07	1.84	24	0.32	0.02	0.05	3.20	24
Potassium (mg/l)	3.30	1.40	2.40	1.32	24	4.30	1.60	2.37	1.30	24
Silica Dissolved (mg/l)	17.55	5.14	13.24	1.25	24	17.55	10.06	13.01	1.12	24
Sodium (mg/l)	84.00	14.00	60.29	1.27	24	150.00	42.00	56.48	1.38	24
Solids Dissolved (mg/l)	606.00	210.00	496.18	1.26	24	1041.00	252.00	502.91	1.38	24
Solids Suspended (mg/l)	429.00	13.00	47.73	2.84	24	820.00	4.00	70.64	4.45	24
Specific Conductance	750.00	740.00	744.98	1.01	2	645.00	645.00	645.00	1.00	2
Sulfate (mg/l)	194.64	41.92	158.34	1.16	24	209.61	59.89	156.11	1.29	24
Turbidity (JTU)	120.00	4.00	23.98	2.84	24	290.00	7.00	25.11	2.46	24

Parameter	NUS Station 29 High	Low	Geo. Mean	Geo. Dev.	No. of Analy.	NUS Station 35 High	Low	Geo. Mean	Geo. Dev.	No of Analy.
Ammonia (mg/l)	0.12	<0.10	0.10	1.04	24	<0.10	<0.10	<0.10	1.00	24
Calcium (mg/l)	86.00	35.00	65.97	1.16	24	84.00	38.00	68.61	1.17	24
Carbon Organic Dissolved (mg/l)	25.00	1.00	7.30	2.01	48	24.00	<1.00	7.69	2.02	48
Chloride (mg/l)	45.00	8.00	33.75	1.35	24	44.00	8.00	30.15	1.35	24
Color (PCU)	35.00	2.50	9.77	2.61	24	25.00	2.50	8.35	3.38	24
Fluoride (mg/l)	0.59	0.27	0.41	1.42	4	0.30	<0.10	0.17	1.89	4
Hardness (mg/l as $CaCO_3$)	376.00	140.00	269.39	1.14	24	344.00	150.00	268.97	1.22	24
Iron Dissolved (µg/l)	<0.02	<0.02	<0.02	1.00	4	<0.02	<0.02	<0.02	1.00	4
Iron Total (µg/l)	1.20	0.24	0.55	2.45	4	2.00	0.22	0.73	1.00	4
Magnesium (mg/l)	37.00	10.00	27.01	1.30	24	33.00	11.00	23.76	1.34	24
Nitrate (mg/l)	1.00	<0.20	0.23	1.53	24	1.00	<0.20	0.23	1.50	24
Nitrite (mg/l)	<0.01	<0.01	<0.01	1.00	24	<0.01	<0.01	<0.01	1.00	24
Nitrogen (mg/l)	2.00	0.15	0.26	1.80	24	1.20	0.10	0.35	2.12	24
Odor (Severity)	0.00	0.00	0.00	1.00	24	0.00	0.00	0.00	1.00	24
Phosphorous Ortho (mg/l)	0.06	0.01	0.02	1.74	24	0.03	<0.01	0.01	1.57	24
Phosphorous Total (mg/l)	0.55	0.02	0.05	2.22	24	0.30	0.02	0.09	4.11	24
Potassium (mg/l)	4.30	1.40	2.28	1.37	24	3.80	1.40	2.41	1.29	24
Silica Dissolved (mg/l)	17.76	10.06	13.01	1.17	24	18.19	9.84	13.27	1.17	24
Sodium (mg/l)	138.00	17.00	66.67	1.54	24	78.00	15.00	57.95	1.25	24
Solids Dissolved (mg/l)	699.00	205.00	471.48	1.38	24	635.00	206.00	479.45	1.24	24
Solids Suspended (mg/l)	1060.00	13.00	74.54	3.00	24	458.00	14.00	68.97	3.58	24
Specific Conductance	785.00	695.00	738.63	1.09	2	740.00	725.00	732.46	1.01	2
Sulfate (mg/l)	212.60	41.92	157.30	1.31	24	191.64	44.92	155.39	1.28	24
Turbidity (JTU)	370.00	6.00	23.34	2.40	24	325.00	6.00	27.69	3.46	24

Drainages within the Piceance Creek basin have not been classified by the Colorado Water Quality Control Commission. The White River has been classified. The White River and tributaries from its source near Trapper's Lake to the mouth of Piceance Creek is quality class B_1. The mainstem of White River from the mouth of Piceance Creek to the Colorado-Utah State Line is quality class B_2. Waters designated class B_1 or B_2 are waters suitable or that may become suitable for all purposes for which raw water is customarily used, except primary contact recreation such as swimming and water skiing.

Grab samples were collected and analyzed by the USGS on a regular preplanned schedule. These samples should be considered as a random sample of all stream flows. Geometric mean conductivities from the grab samples were compared to median continuous conductivity values at stations for which data were available.

These comparisons indicated that Box Elder Gulch near west line of Tract C-a showed a greater range and higher average for the grab samples than for the continuous data. This station may be biased toward higher total dissolved solids (TDS), thus the population means derived from grab samples will probably be lower than the sample means.

Corral Gulch near the west line of Tract C-a shows very good agreement between geometric mean of conductivity for the grab samples and median continuous data. The range of data is somewhat greater for the continuous data, however, the population estimates are probably accurate.

Corral Gulch near the east line of Tract C-a shows almost identical distributions for grab samples and continuous conductivity as did Yellow Creek near White River.

Table 2.17 compares the water quality limits on various constituents for range animals with the waters found at the four gaging stations that have perennial flows. With the exception of fluoride (F) at the Yellow Creek gaging station, none of the limits are expected to be exceeded based on the two years of data collected to date. Fluoride at the Yellow Creek gaging station will exceed the limit of 2 mg/l estimated 23 percent of the time.

TABLE 2.17
WATER QUALITY LIMITS
RANGE ANIMALS AND SURFACE WATER

	Limits[1]	Box Elder Gulch Probability+ Limit Exceeded	Corral Gulch West Probability+ Limit Exceeded	Corral Gulch East Probablility+ Limit Exceeded	Yellow Creek Probability+ Limit Exceeded
Arsenic (mg/l)	0.15	0	0	0	0
Cadmium (mg/l)	0.01	0	0	0	0
Chromium (mg/l)	0.05	0	0	0	0
Fluoride (mg/l)	2.00	0	0	0	23
Lead (mg/l)	0.05	0	0	0	0
Selenium (mg/l)	0.01	0	0	0	0
TDS (mg/l)	10,000	0	0	0	0
Radium (pc/l)	3	*	*	*	*
Strontium (pc/l)	10	*	*	0	0

\+ Percent of Time

* Insufficient Data

1 McKee & Walt; 1963, Todd, 1969, EPA 1973

The drinking water quality standards, specifically the USPHS limits were compared to the surface waters at the four gaging stations. Of the various types of limits, (i.e., recommended maximum or unestablished) only constituents having recommended limits were found to have a probability of exceeding that limit on or immediately around Tract C-a. The constituents which may exceed the limits are sodium (Na), sulfate (SO_4), and TDS. Because the limits are just slightly exceeded, and these are recommended limits, this water would be perfectly acceptable under these criteria for drinking water purposes. Table 2.18 summarizes this comparison.

The water at the Yellow Creek gaging station would not be considered potable much of the time because of cadmium (Cd), F, Na, SO_4, and TDS. In addition, hardness would be a severe problem in using the water for domestic purposes. The water qualities, as a comparison of the percent difference in water constituent concentrations on and around Tract C-a, are shown on Table 2.19. The values given are determined by comparing the water quality at two different locations; the first location value minus the second location value, and the result divided by the first location value.

In summary, the reach of Corral Gulch within Tract C-a is found to have increasing values for all of the constituents with the exception of nitrate and nitrite.

The proportional relationship between major cations and anions was investigated using a trilinear diagram which is useful in discriminating major water quality types (Figure 2.17). Sample analysis from Tract C-a show that surface water cannot be distinguished from spring and alluvial water types. Surface water is partially associated with typical upper aquifer water but no association is apparent with lower aquifer water type.

Within the tract, the Corral Gulch sampling site has greater relative concentrations of SO_4 and Chlorine (Cl) than the Box Elder sampling site. This probably is due to the contribution of SO_4 water from Maverick Spring on Corral Gulch. No Yellow Creek surface water type is representative of a combination of upper and lower aquifer type water. Yellow Creek water contains considerably more

TABLE 2.18

DRINKING WATER QUALITY LIMITS

COMPARED WITH

SURFACE WATER QUALITY AT MONITORING SITES

	USPHS Limits	Box Elder Gulch		Corral Gulch West		Corral Gulch East		Yellow Creek	
		Mean +	Probability[1] Limit Exceeded	Mean +	Probability[1] Limit Exceeded	Mean +	Probability[1] Limit Exceeded	Mean +	Probability[1] Limit Exceeded
Arsenic (mg/l)	0.05	0.006	0	0.004	0	0.005	0	0.004	0
Barium (mg/l)	1.00	0.075	0	0.078	0	<0.074	0	0.165	0
Cadmium (mg/l)	0.01	0.004	0	0.004	0	0.003	0	0.003	2
Chloride (mg/l)	250.00	5.57	0	7.61	0	9.78	0	125.91	0
Chromium (mg/l)	0.05	0.003	0	<0.002	0	0.003	0	0.003	0
Copper (mg/l)	1.00	0.003	0	0.003	0	0.002	0	<0.003	0
Cyanide (mg/l)	0.20	0.01	0	<0.01	0	0.01	0	<0.01	0
Fluoride (mg/l)	2.40	0.33	0	0.25	0	0.49	1	2.26	30
Iron (mg/l)	0.30	0.018	0	0.043	2	0.031	0	0.026	0
Lead (mg/l)	0.05	0.003	0	0.003	0	0.002	0	0.002	0
Manganese (mg/l)	0.05	0.010	0	0.012	1	0.017	4	0.012	0
Nitrate (mg/l)	45.00	4.12	0	4.01	0	1.22	0	4.80	0
Selenium (mg/l)	0.01	0.004	0	0.004	0	0.003	0	0.002	0
Silver (mg/l)	0.05	<0.001	0	<0.001	0	<0.002	0	<0.003	0
Sodium (mg/l) #	115.00	42.90	0	84.86	0	109.15	25	778.28	100
Sulfate (mg/l)	250.00	125.57	25	282.92	95	288.77	92	556.14	100
TDS (mg/l)	500.00	468.27	40	739.52	100	822.87	100	2512.67	100
Zine (mg/l)	5.00	0.015	0	0.015	0	0.013	0	0.013	0
$Radium_{226}$ (pc/l)	3.00	--	--	--	--	--	--	--	--
$Strontium_{90}$ (pc/l)	10.00	--	--	--	--	--	--	--	--
Hardness (mg/l) #	500.00	313.20	20	460.36	2	476.06	25	530.16	60

1 Percent of Times
\+ Geometric Mean
* Insufficient Data
\# Unestablished Limit

TABLE 2.19
STREAM REACH COMPARISON OF
PERCENT DIFFERENCE IN WATER CONSTITUENT CONCENTRATIONS
OVER TRACT C-a

Location	Ortho PO_4	Hard-ness	Ca	Mg	Na	K	Cl	SO_4	Si	Dis. Solids	N as NH_4	N as NO_3	N as NO_2
Corral Gulch west as opposed to Box Elder west	0	+ 27	+ 16	+ 39	+ 80	+ 50	+ 27	0	- 8	+ 45	0	- 31	-100
Reach of Box Elder Gulch bet. W.Line Tract C-a to approx. 50 metres below seepage area	+100	+ 28	+ 21	+ 22	+ 55	+ 41	+ 54	- 28	- 4	+ 38	0	- 60	-100

Sodium bicarbonate ($NaHCO_3$) than Tract C-a water. The proportion of Calcium (Ca) to other major constituents is less, perhaps due to precipitation in the alluvium.

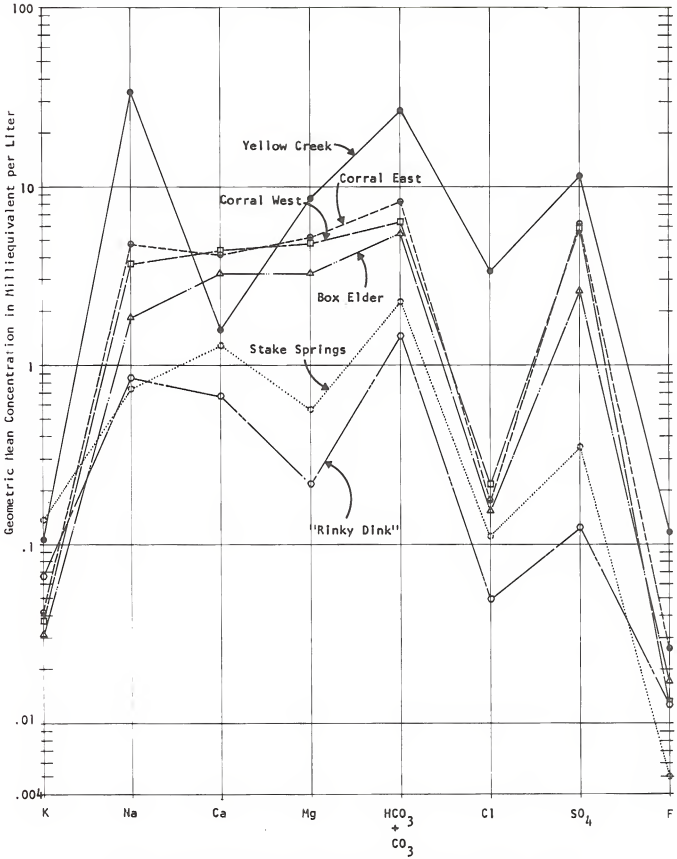
Figure 2.18 shows the comparison of the averages of major constituent concentrations. Stake Springs near the confluence with Corral Gulch and "Rinky Dink" Gulch samples were collected during snowmelt runoff, as compared to other sites which are influenced by groundwater contributions.

Initial examination of surface water quality data suggested that the variation in concentrations of various chemical components was not totally independent; that there were interrelationships between chemical parameters. This is suggested because surface water on and near Tract C-a is composed of varying portions of four components which are:

- Deep groundwater discharge
- Interflow discharge
- Surface wash-off
- Alluvial emergence

that have distinctive water quality characteristics. The winter base flow period, for example, shows the highest conductivities with associated high values for many of the chemical parameters. This period is probably the most representative of diffuse and point groundwater discharge as modified by contact with the alluvium.

In order to determine which of the chemical parameters were correlated with each other, correlation and regression analyses were run on log-transformed data (with the exception of pH which is already in log form) of selected chemical parameters. The disadvantages of this type of correlation analysis is that the effects of variables other than the two parameters under consideration are not taken into account. The largest data base available is conductivity data for any of the water quality parameters collected. It was used to see if there was some way of predicting other chemical parameters from conductivity alone. Scattergrams of conductivity versus most of the other variables were prepared for the two Corral and Box Elder Gulch stations and each of these stations individually in order to visually examine the relationship of various chemical constituents and conductivity.



AVERAGE CONCENTRATION OF CHEMICAL CONSTITUENTS IN SURFACE WATER

FIGURE 2.18

As can be seen for the correlation matrices and scattergrams of conductivity versus other parameters, not all of the major parameters may be predicted with any degree of confidence (Figure 2.19). The relationship between conductivity and TDS is nearly linear, as would be expected. Sodium, Cl, and bicarbonate (HCO_3) show very high positive correlations with conductivity and the values for the parameters may be estimated with some degree of confidence from conductivity data alone.

Correlation matrices are presented in RBOSP Progress Report 10 and summaries are shown on Figures 2.20 through 2.23. These summary matrices show significant correlations at the 5 percent confidence level with a "+" for direct correlation (i.e., when concentration of one parameter increases, the other one also tends to increase), and a "-" for inverse correlations. Results are presented separately for four stations, Corral west, Box Elder, Corral east, and Yellow Creek, while Corral west, Corral east and Box Elder are combined in the matrix in Figure 2.24 (see p. II-14 for Station ID numbers).

Box Elder Gulch near the west line of Tract C-a flows only during snowmelt or intense rainfall events, so correlations at this station mainly represent surface runoff and some interaction with alluvium and possible interflow discharge. All of the major anions and cations except Potassium (K) increase with increasing flows. Reduced nitrogen (N) compounds and the heavy metals (i.e., iron (Fe), and phosphates (PO_4) are highest during low flows. Heavy metals more abundant in high flows selenium (Se), lithium (Li), and strontium (Sr). Parameters showing a high degree of correlation with conductivity were HCO_3, ammonium (NH_4), Ca, magnesium (Mg), Na, K, Cl, SO_4, F, silicon dioxide (SiO_2), Sr, Li, Se, TDS.

The water entering the tract at Corral Gulch shows moderate correlation between the major constituents: Ca, Mg, Na, K, Cl, SO_4, HCO_3, and TDS. The correlation of nitrite (NO_2) and nitrate (NO_3) with Ca, Na, Cl, F, and arsenic (As) and the lack of correlation with NH_4 is suggestive that some of these constituents are associated with an oxidizing surface source. These constituents could leach near-surface Unita material, such as halite, sulfides, and dolomite minerals. A sulfide mineral solution may relate to correlations between lead (Pb) and zinc (Zn), Fe, Cd, and copper (Cu) with Fe and Pb. Phosphate mineral solution (as apatite) could contribute to the correlation between Ca, F, and PO_4.

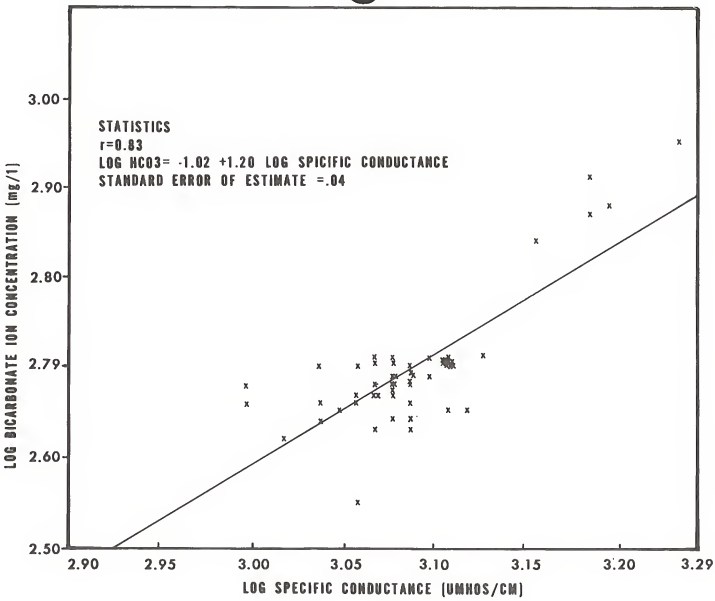


FIGURE 2.19

RELATIONSHIP BETWEEN SPECIFIC CONDUCTANCE AND BICARBONATE CONCENTRATION AT CORRAL GULCH, NEAR EASTERN BORDER OF TRACT C-a

FIGURE 2.20

BOX ELDER GULCH WATER CONSTITUENT SIGN CORRELATION MATRIX

	TEMP	ICFS	COND	DO	pH	HCO3	CO3	NH4	KJAN	NO2 AND 3	PO4	ORTHO PO4	SULFIDE	HARDNESS	CA	MG	NA	K	CL	SO4	F	SIO2	AS	BA	B	CD	CR	CU	FE	PB	MN	SR	ZN	LI	SE	TDS	HG
Temperature		+		-								-				+	+		+	+		+		+					-		-							
Instantaneous Flow			+			+		-		+		-		+	+	+	+	-	+	+	+	+							-		-	+			+	+		
Specific Conductance		+		+				-		+	-	-		+	+	+	+	-	+	+	+	+			+						-	+		+	+	+		
Dissolved Oxygen					+										+	+								-			-				+				+		
pH																														-							
Bicarbonate									-		+		-		+	+	+	+	-	+	+	+			+									+	+	+		
Carbonate																																					
Ammonia										-		+		-	-	-	-	+	-	-	-	-			-		+	+				+	-	-	-		
Kjeldahl Nitrogen										+				+							+										+		-				
Nitrate plus Nitrite												-		+	+	+	+	-		+	+	+			+									+	+		
Phosphate (PO_4)																												+		+	-		-				
Ortho Phosphate (PO_4)														-	-	-	-	+	-	-	-	-			-			+		+	-		-		-	-	-	
Sulfide																															+						
Ca, Mg Hardness															+	+	+	-	+	+	+	+			+							+		+	+	+		
Calcium															+	+	-	+	+	+	+	+			+									+	+	+		
Magnesium															+	-	+	+	+	+	+										-	+		+	+	+		
Sodium																-	+	+	+	+	+										-	+		+	+	+		
Potassium																-	-	-	-	-								+	+		+	-		-	-	-		
Chloride																	+	+	+	+					+						-	-	-	+	+	+		
Sulfate																		+	+	+											-	+		+	+	+		
Fluoride																				+					+										+	+		
Silica																															-	+		+	+	+		
Arsenic																													+		+	+						
Barium																																					+
Boron																																			+		
Cadmium																											-					-					
Chromium																																					
Copper																													+			-					
Iron																														+			-	-			
Lead																																+					
Manganese																																	-		-		
Strontium																																			+		
Zinc																																	-				
Lithium																																			+		
Selenium																																			+		
Total Dissolved Solids																																					
Mercury																																					

ICFS - Instaneous Flow (cu ft/sec)

FIGURE 2.21

CORRAL WEST WATER CONSTITUENT SIGN CORRELATION MATRIX

	TEMP	TCFS	COND	DO	HCO3	CO3	NH4	KJAN	NO2 AND 3	PO4	ORTHO PO4	SULFIDE	HARDNESS	CA	MG	NA	K	CL	SO4	F	SIO2	AS	BA	B	CD	CR	CU	FE	PB	MN	SR	ZN	LI	SE	TDS	HG
Temperature				-	-									-	-										-									+	..	-
Instantaneous Flow					+		-				-								-			+									+					
Specific Conductance														+			+																		+	
Dissolved Oxygen					+												+			+	-												-		+	+
pH																						-														
Bicarbonate														+	+	+					+									+					+	+
Carbonate																																				
Ammonia																			+								+				-					
Kjeldahl Nitrogen											+																	+				+				
Nitrate plus Nitrite												+		+	+		-		-	-	+	+	+													
Phosphate (PO_4)																					+					-										
Ortho Phosphate (PO_4)																				+					-											
Sulfide																																				
Ca, Mg Hardness														+	+			-													-				+	
Calcium																		-		+			+		-										+	
Magnesium																															-				+	+
Sodium																		+	+																+	+
Potassium																		-			-										-					
Chloride																			+															-		
Sulfate																			-															-	+	
Fluoride																				+			+			+						+				
Silica																					+										-					
Arsenic																								+												
Barium																								+								+				
Boron																										-	-									
Cadmium																										-		-								
Chromium																											+									
Copper																												+	+							
Iron																												+		+	-					
Lead																															+					
Manganese																																			+	+
Strontium																																				
Zinc																																				
Lithium																																				
Selenium																																		-		
Total Dissolved Solids																																				
Mercury																																				

FIGURE 2.22

CORRAL EAST WATER CONSTITUENT SIGN CORRELATION MATRIX

	TEMP	ICFS	COND	DO	pH	HCO3	CO3	NH4	KJAN	NO2 AND 3	PO4	ORTHO PO4	SULFIDE	HARDNESS	CA	MG	NA	K	CL	SO4	F	SIO2	AS	BA	B	CD	CR	CU	FE	PB	MN	SR	ZN	LI	SE	TDS	HG
Temperature	+	-	-		-										-		-				-			+						+	-	-			-	-	
Instantaneous Flow	+	-	-	+	+				+	+	+			-	-	-	+	+	+	-	+				+		-				-					+	
Specific Conductance						+		+	+		+				-		+	+	+	+	+				+									+			+
Dissolved Oxygen												-				+	+	+			+	-	-		-		+				+							
pH															-	-				-	+										-							
Bicarbonate						+	+				+				+	-		+	+	+		+			+										+	-	+	+
Carbonate																																					
Ammonia								+			+					-		+	+	+		+	-		+											+	
Kjeldahl Nitrogen									+	+				-	-	-	+	+	+	-	+	+			+							-				+	
Nitrate plus Nitrite											+				-		-	-			-		+						+		-			+	-		
Phosphate (PO_4)												+			-	-	-	+		+	-	+			+		-											
Ortho Phosphate (PO_4)																												+		+							
Sulfide																													+					+			+
Ca, Mg Hardness														+	+	-			-	+	-		-		-						+							
Calcium															+	-			-	+	-				-		+							-				
Magnesium																				+	-	-	-		-						+					+	
Sodium																	+	+		+	-				+		+					+		+	-	+	
Potassium																		+		+					+											+	
Chloride																				+					+						+	+		+	-		
Sulfate																				-		-			-						+	+				+	
Fluoride																									+									+	-	+	
Silica																										-									+	-	
Arsenic																													+			-	+		+		
Barium																											+	-	-		-						
Boron																										-								+	-	+	
Cadmium																											-						-				
Chromium																																			+		
Copper																													+	+	-		+				
Iron																																-	+	-	+		+
Lead																																	+		+		
Manganese																																			-	+	
Strontium																																				+	+
Zinc																																					+
Lithium																																					
Selenium																																				-	
Total Dissolved Solids																																					+
Mercury																																					

FIGURE 2.23

YELLOW CREEK WATER CONSTITUENT SIGN CORRELATION MATRIX

	TEMP	ICFS	COND	DO	pH	HCO3	CO3	NH4	KJAN	NO2 AND 3	PO4	ORTHO PO4	SULFIDE	HARDNESS	CA	MG	NA	K	CL	SO4	F	SIO2	AS	BA	B	CD	CR	CU	FE	PB	MN	SR	ZN	LI	SE	TDS	HG
Temperature	-		-	+			-		-	-	-	-		-	-							-	+								-							-
Instantaneous Flow			+	-				+		+	+	+		+	+	+	-		-		-	+			-													
Specific Conductance					+		-			-					+	+	+		+	+	+				+						-			+		+		
Dissolved Oxygen								+		+		+		+													+					+					
pH						+	-			-		-				-						-									-							
Bicarbonate							-										+		+	+		+			+									+		+		
Carbonate																						+																
Ammonia										+		+		+	+	+			-	-		+	-		-						+		+					+
Kjeldahl Nitrogen											+											-												-				
Nitrate plus Nitrite												+		+	+		-		-	-	-	+			-						+			-		-	-	+
Phosphate (PO_4)												+			+		-	+			-	+			-	-								-				
Ortho Phosphate (PO_4)													+	+	+		-		-			+								+								
Sulfide																												-			-						
Ca, Mg Hardness															+	+		-		+		+	-					-			+				-			
Calcium																-	-		-		-	+		+							+	+		-		-		
Magnesium																	+	-		+	+										-			+	-	+		
Sodium																			+	+	+					+					-			+		+		
Potassium																					-						-		+			-	-	-		-	-	
Chloride																					+					+					-			+		+		
Sulfate																					+													+	-	+		
Fluoride																					-									+				+	-	+		
Silica																																						
Arsenic																												+			-	-						
Barium																																						
Boron																										-	-				-					+		
Cadmium																												-	-								+	
Chromium																											+		+									
Copper																													+	+								
Iron																														+	+						-	
Lead																																						
Manganese																																		-		-		
Strontium																																						
Zinc																																						
Lithium																																				+		
Selenium																																						
Total Dissolved Solids																																						
Mercury																																						

FIGURE 2.24

COMBINED STATIONS WATER CONSTITUENT SIGN CORRELATION MATRIX

	TEMP	ICFS	COND	DO	pH	HCO3	CO3	NH4	KJAN	NO2 AND 3	PO4	ORTHO PO4	SULFIDE	HARDNESS	CA	MG	NA	K	CL	SO4	F	SIO2	AS	BA	B	CD	CR	CU	FE	PB	MN	SR	ZN	LI	SE	TDS	HG
Temperature		-	-		+	-		-		+		-				-															-			+	+		-
Instantaneous Flow	+				+					-					+	+	+		+	+	+	+			+			-	-			+				+	
Specific Conductance				-	+					-					+	+	+		+	+	+	+			+			-			+	+				+	
Dissolved Oxygen				-						-					+	+	+			+	-										+	+		-		+	
pH					-					+		-			-	-	-	-	-	-		-					-				-				+	-	
Bicarbonate										-					+	+	+	+		+	+	+			+			-	-		+	+				+	
Carbonate																																					
Ammonia					+	-			+					-	-	-			+	+	-	+	-		+			+	+		+	-			-		+
Kjeldahl Nitrogen					+	+								-	-	-				-	+				+				+			-	+				+
Nitrate plus Nitrite																	-		-			+	+		-						-		-		-	+	-
Phosphate (PO_4)															-	-	-		+		-	+			+		-		+		+	-				-	
Ortho Phosphate (PO_4)															-	-	-		+		-	+				-		+			+	-			-		
Sulfide																																					+
Ca, Mg Hardness															+	+	+	-	+	+		+	-					-				+				+	
Calcium																+	+	-	+	+		+						-				+			+	+	
Magnesium																+	-	+	+		+	-			+			-	-			+				+	
Sodium																		+	+	+	+				+			-	-			+				+	
Potassium																		+	-	+					+			+	+		+	-			-		
Chloride																			+	+					+				-		+	+			-	+	
Sulfate																					+	-			+			-	-			+			-	+	
Fluoride																					+				+							+		+	-	+	
Silica																						+										+	-	+		+	
Arsenic																								+	+				+		-	+		+	-		
Barium																									+		-	-			-			+			
Boron																										-		-				+				-	+
Cadmium																											-	-	-	-		-					
Chromium																													+						-		
Copper																												+	+		-					-	
Iron																													+		-	+	-			-	
Lead																																	+				
Manganese																																			-		+
Strontium																																		+		+	
Zinc																																	-				+
Lithium																																					
Selenium																																					
Total Dissolved Solids																																					
Mercury																																					

The Corral Gulch east sampling station correlation data show considerably greater overall correlation of chemical constituents than the west stations. This is in part due to a greater number of samples (approximately 20 percent) from the Corral east station. It is apparent that a considerably more significant relationship exists between nitrogen (N) and PO_4 than with other constituents. Also, the correlation among the major constituents is considerably greater. Boron (B) and F show strong similar relationships with many constituents. Selenium and Li show a fair degree of correlation with other constituents. The correlation among major constituents is suggestive of a groundwater contribution that is seasonally diluted by mixing the alluvium.

Those constituents that show direct correlation with each other are Ca, Mg, and Se, (group "a") and P, Na, F, Li, B, and NH_4, (group "b"). Group "a" has an indirect correlation with group "b".

It is possible that the former group of constituents represents winter aquifer base flow groundwater contribution with constituents perhaps due to the dissolution of dolomite and associated minerals. The latter group of constituents may result from surface leaching or alluvial flushing of sulfide and possibly phosphate minerals due to spring snow melt. Ammonium may result from the reduction of NO_2 and NO_3 in the alluvium, when flushing occurs during spring snowmelt.

Notwithstanding that more analyses were used for the Corral Gulch east station than for Corral Gulch west, it appears that there is a significant difference between water chemistry relationships at the Corral Gulch stations. On the basis of correlation and regression analysis, it seems that an added source of water is present at Corral Gulch east that is not present at Corral Gulch west. This probably stems from the contribution of water from Box Elder Gulch or springs in the vicinity of the confluence of Box Elder Gulch with Corral Gulch.

When the data from the three tract stations were pooled, the number of significant correlations increased; partly due to the larger number of analyses and partly due to a general increase downstream for all parameters. This general similarity in interrelationships downstream reinforces the assumption that

the tract stations may be treated as the same general hydrologic system. There are, however, some significant differences between the east and west tract stations.

The most significant difference is the reversal in the correlations of reduced N and PO_4's with flow. At the upper tract stations, these parameters generally tend to increase at high flows. This trend is marginal for reduced N at Corral Gulch near the eastern border only on the correlation coefficient; however, when seasonal trends are observed, reduced N and PO_4's tend to be associated with the first portion of snowmelt runoff. This also suggests a flushing effect from the alluvial aquifer.

Yellow Creek showed several important differences from the tract station. The most important of the differences is the interrelationship with Ca. Calcium is directly correlated with Mg and SO_4 on tract by an inverse correlation existing on Yellow Creek. Significant direct correlations with flow were detected for dissolved oxygen (O), NH_4, NO_3, NO_2, and NO_3, PO_4, Ca, Mg, and SiO_2. Most of the differences in correlation can be explained by the discharge of lower aquifer water to Yellow Creek that is subsequently diluted by upstream runoff during the snowmelt period.

There is also a reversal in the correlation of TDS with flow from that observed on tract. This suggests that the surface runoff serves to dilute the base flow at Yellow Creek, while on-tract surface runoff effects are about the same for TDS or somewhat higher than base flow. Calcium, Mg, SO_4, and Cl also increase with flow at Yellow Creek suggesting that these constitutents are associated with surface runoff in the vicinity or are carried in from upstream reaches.

In order to further look at interrelationships between chemical parameters and hydrology, a multivariate statistical technique known as factor analysis was used. The structure of the correlation matrix of chemical parameters is very complex. Factor analysis attempts to simplify the information contained in a correlation matrix into weighted combinations of variables or factors. It is used to redistribute the explained variance present in the correlation coefficient matrix into a set of factors that are linear combinations of the original variables.

Factor analysis was completed on the pooled water quality data for stations 09306235 (Corral near west line Tract C-a), 09306240 (Box Elder Gulch near west line Tract C-a), and 09306242 (Corral Gulch near east line Tract C-a). These three stations were pooled because it was assumed that they were part of the same general hydrologic and hydrogeologic population. Parameters retained for factor analysis were selected so that no derived variable, i.e., bicarbonate and carbonates from alkalinity and pH, or TDS, were retained in the data set. This was to assure there would be no spurious intercorrelations that would tend to mask meaningful variations in the data set (Table 2.20).

Sixty-five water samples analyzed for twenty-six parameters were used as the input data for the factor analysis on the three gaging stations associated with Tract C-a. Water quality data for the period March 1974 through September 1976 were used. Plots were constructed of the new synthetic variables and interpretations of the importance of each of these factors between stations at a particular time and within stations across time were constructed to aid in interpretation of each of the factors. The SPSS package (Nye, et al. 1975) was used for the actual calculations.

All chemical analyses from Corral Gulch near west line Tract C-a, Box Elder Gulch near the western border of Tract C-a and Corral Gulch near the east line of Tract C-a were pooled for the factor analysis. Two subsets of parameters were analyzed, the first of which included Ca, Mg, Na, K, Cl, SO_4, pH, and specific conductance. Two factors were extracted and rotated using the varimax criterion from the principal components matrix. The resulting communalities, factor loadings, and percent of variance accounted for are shown in Table 2.20. The communalities shown are a percent of the variance of each parameter that is explained by the extracted factors.

The first factor, which accounts for 52 percent of the variance in the data set is composed of Na and Cl. Conductivity probably represents groundwater contributions to streamflow. The second factor is composed of Ca and Mg, and SO_4 accounts for 15 percent of the remaining variance. Together these two factors account for 67 percent of the variance in the data set with the remaining 33 percent due to random variation unaccounted for by

TABLE 2.20

VARIMAX FACTOR LOADING MATRIX OF MAJOR CHEMICAL CONSTITUENTS

FOR 113 ANALYSES FROM TRACT C-a SURFACE WATER MONITORING STATIONS *

Variable	FACTOR 1	FACTOR 2	Communality
Specific Conductance	.856	.361	.862
pH	-.201	-.368	.176
Ca	-.020	.780	.608
Mg	.349	.784	.737
Na	.947	.172	.926
K	.606	.262	.435
Cl	.892	.148	.818
SO_4	.388	.784	.766
Percent Variance Explained	51.6%	15.0%	
Cumulative Percent	51.6%	66.6%	

* Loadings less than 0.2 omitted.

the two extracted factors. Factor scores were calculated and plotted on hydrographs to aid in interpretation. The hydrograph of factor scores 1 and 2 are shown on Figure 2.25 for Corral Gulch near the east line of Tract C-a, and on Figure 2.26 for Corral Gulch near the west line Tract C-a.

The value of the factor score is as a relative index of the importance of that factor in accounting for the variance. Factor 1 is highly loaded on parameters that are abundant in ground water due to dissolution of nacholite and very minor amounts of halite. The response of the hydrograph of factor 1 to various stream flows suggests that the highly soluble components in the factor increase during summer storm events--possibly due to surface washoff or interflow discharge.

From April through June 1975 during the aquifer testing program on C-a, factor 1 showed the highest values of the baseline period at the Corral east station. Anomalous low values of factor score 1 occurred during the snowmelt period of water year 1974. More gradual increases were observed during the snowmelt period of water year 1976.

During base flow periods, the value of factor 1 remained relatively stable, reflecting the input of deep groundwater discharge. Based on the analysis of the factor scores it is very difficult to separate the surface washoff effects from groundwater discharge. This conclusion agrees with that based on the analysis of continuous specific conductance data. Part of the reason for this is the excellent interconnection of Corral Gulch with the alluvium in the lower reaches on C-a.

Corral Gulch near the west line of Tract C-a generally shows less variation in the factor score range than the lower Corral Gulch station. In water years 1974 and 1975 factor score 1 was at a low point during the snowmelt period; however, in water year 1976, which had a less distinct snowmelt runoff, factor 1 was higher. Factor score 2 generally exceeds factor 1 at this station.

Factor score 2 at Corral Gulch near the east line of Tract C-a generally parallels the trend of factor score 1 during periods of base flow, however, during snowmelt or storm runoff periods there is an inverse relationship. The exception to this was the last phase of snowmelt during water year 1974.

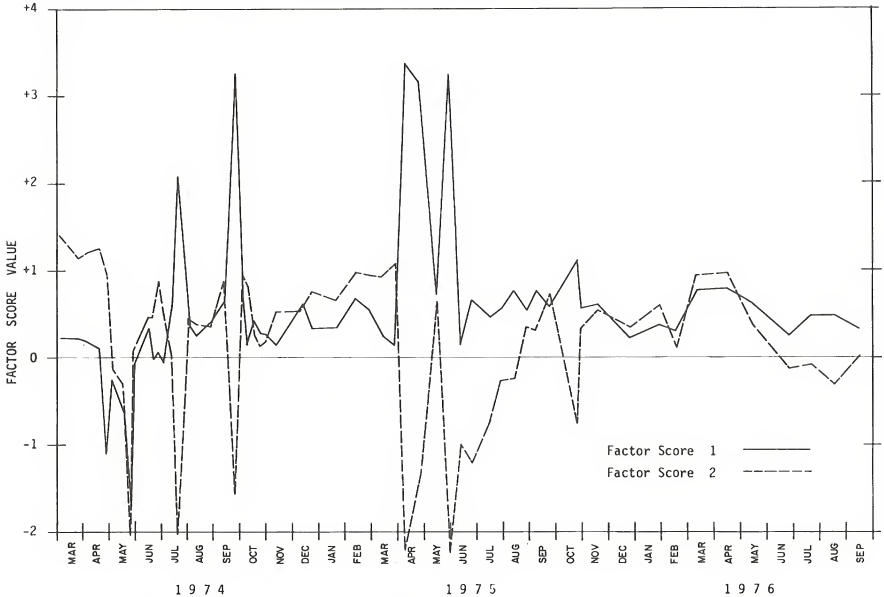


FIGURE 2.25

FACTOR SCORE HYDROGRAPH FOR CORRAL GULCH NEAR THE EASTERN BORDER OF TRACT C-a

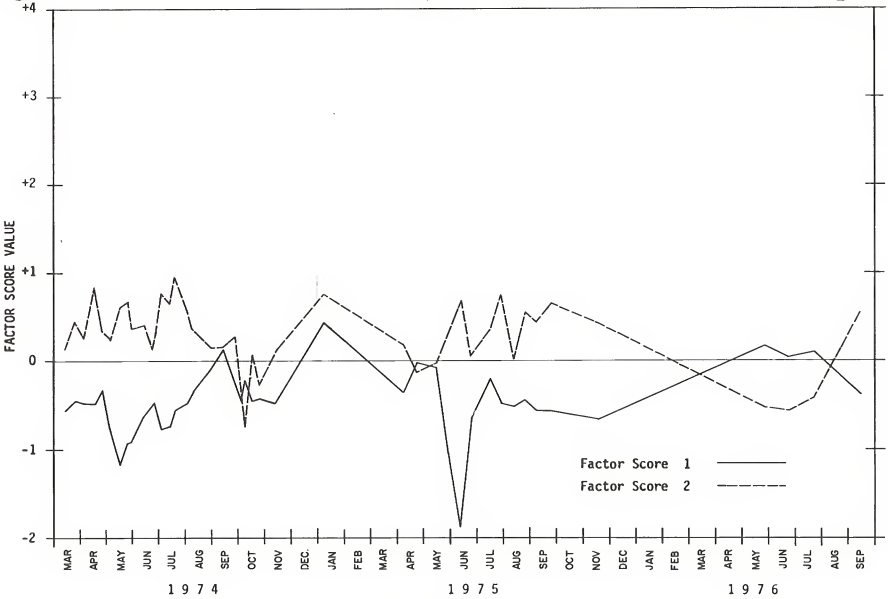


FIGURE 2.26

FACTOR SCORE HYDROGRAPH FOR CORRAL GULCH NEAR

THE WESTERN BORDER OF TRACT C-a

Factor score 2 generally reaches a high prior to beginning of snowmelt, shows low and variable values during snowmelt and storm periods, and shows gradual recovery to highs during the summer and fall. Factor 2 represents the interaction with water in the alluvium. There are several possible reasons for this grouping of parameters in factor 2.

The association of Ca, Mg, and SO_4 suggests that dissolution of minor gypsum or anhydrite may play a role. The more likely explanation, however, is that springs and diffuse seepage areas in the upper reaches of the Corral basin supply water to underflow in the alluvium that undergoes concentration of dissolved solids by phreatophitic evapotranspiration. Dilution of this water in transient storage within the alluvium takes place during snowmelt or intense summer storms when sodium carbonate rich waters infiltrate the alluvium. This is reflected in lower values for factor 2 after the snowmelt season, with the rise taking place during summer and fall due to draining of the alluvium and contribution of a greater portion of Ca, Mg, and SO_4 rich waters.

There is some suggestion that Ca concentration may be controlled by equilibrium with solids in that there is a moderate inverse correlation between Ca and pH.

A second factor analysis was completed on the combined tract station data base, using a larger subset of chemical parameters as shown on Table 2.21. In this table, the factor loading which accounts for more than 2 percent of the covariance are shown. The results on the major constituents remain the same as the first factor analysis; however, in factor 1, B and F showed high direct correlations with the Na, K, HCO_3, Cl, and conductivity. Ammonia nitrogen is moderately loaded in this factor and shows a high inverse correlation with the oxidized nitrogen species.

The first factor again represents a combination groundwater, interflow, and surface washoff mechanism. Boron and F are very highly associated with ground water near C-a and suggest major contributions of deep groundwater in this factor. During periods when surface washoff is acting, overland flow is the dominant mechanism of water contribution to the stream and dilutes all other sources. In this surface washoff, oxidized nitrogen species are carried to the streams and infiltrate the alluvium.

TABLE 2.21

VARIMAX FACTOR LOADING MATRIX OF CHEMICAL DATA FOR 84 ANALYSES FROM TRACT C-a SURFACE WATER MONITORING STATIONS *

Variable	FACTOR 1	2	3	4	5	6	Communality
Specific Conductance	.833	.428					.906
pH		-.461			-.214	-.266	.358
PO_4						.614	.418
$NO_2 + NO_3$	-.284		.821				.803
HCO_3	.914	.249					.910
Ca		.787				-.216	.677
Mg	.220	.775			-.222	.212	.747
Na	.911	.281					.944
K	.519	.318	.330		-.305	.246	.636
Cl	.792	.277				.231	.804
SO_4	.238	.787			-.292		.773
F	.829	-.336			.230		.898
SiO_2			.782		.289	.240	.782
As			.256		.662		.528
B	.830						.714
Cd				-.516			.334
Fe		.233		.575			.407
Pb				.599	.261	.207	.482
Mn	.221	.449				.287	.378
Zn			-.262	.651	.323		.625
Li		-.296		-.275		.263	.259
Se	-.398		.243	.231		-.268	.365
Percent Variance Explained	28.3%	11.6%	7.8%	7.6%	3.6%	3.4%	
Cumulative Percent	28.3%	39.9%	47.7%	55.3%	58.9%	62.3%	

* Loadings less than 0.2 omitted

During other times with little washoff, oxidized N species undergo reduction within the alluvium and are discharged to the stream. There is complexity in the mechanism in that the alluvial water undergoes a transition from an oxidizing environment during late spring and summer to a reduction environment during fall and winter.

Based on the second factor analysis, it appears that the alluvium interaction plays some role in factor 1; however, it is mainly controlled by groundwater and interflow moving into the alluvium.

Factor 2 remained about the same as in the first analysis except that Mn was moderately loaded in this factor. The interpretation of this factor remains the same as before in that spring and seep water from the upper reaches interacting with the alluvium contribute to this factor.

Factor score 3 is loaded mainly on NO_2 and NO_3, and SiO_2, thus probably represents a surface washoff parameter. Factor 4 is composed mainly of heavy metals and shows Fe, Pb, Zn, and Se inversely correlated with Cd and Li. The communalities of most of the heavy metals are low, showing there is a large portion of unexplained variance. This may be due to control of these parameters by organic complexes.

A factor analysis on major components for Yellow Creek was completed and the factor loading matrix is shown on Table 2.22. Results from this analysis differ somewhat from that on tract. Most of the variation is explained by Na, Cl, alkalinity and specific conductance. The second factor shows Mg and SO_4 simultaneously inversely correlated with K while the third factor consists mainly of Ca. The factor score hydrograph for this station is shown on Figure 2.27. Factor 1 shows a distinct general increase over the baseline period. This may be due to below average runoff in water years 1975 and 1976.

A factor analysis on major components for the White River was completed and the factor loading matrix follows. Most of the variation is explained by Ca, Cl, Mg, Na, SO_4, and TDS, see page II-72.

TABLE 2.22

VARIMAX FACTOR LOADING MATRIX OF MAJOR CHEMICAL CONSTITUTENTS FOR ANALYSES FROM YELLOW CREEK NEAR WHITE RIVER *

Variable	FACTOR 1	FACTOR 2	FACTOR 3	Communality
Ca	-.203		-.783	.655
Mg		.843	.373	.870
Na	.909	.241	.260	.951
K		-.513		.296
Cl	.873		.257	.840
SO_4		.735	.202	.602
Alkalinity	.935	.284		.979
pH			.365	.173
Specific Conductance	.613	.371		.549
Percent Variance Explained	43.8%	14.6%	7.3%	
Cumulative Percent	43.8%	58.4%	65.7%	

* Loadings less than 0.2 omitted.

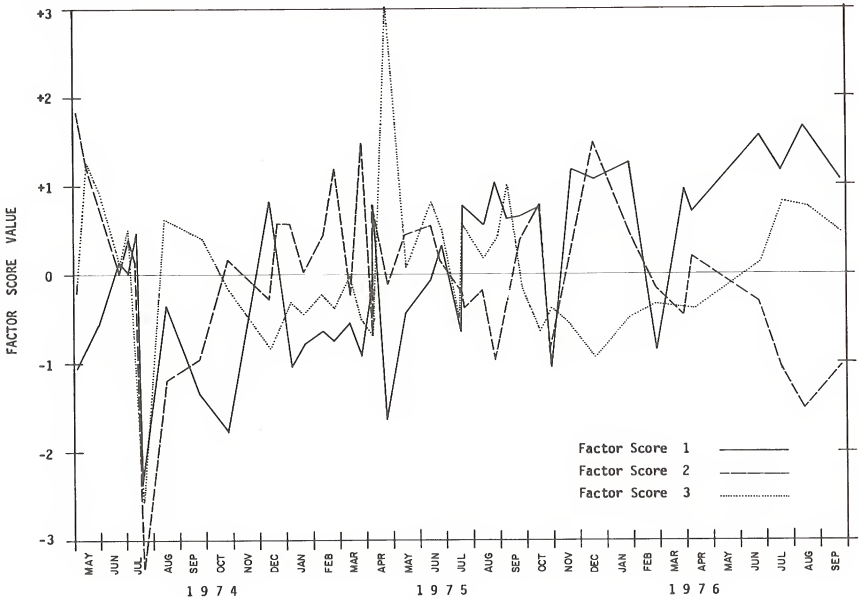


FIGURE 2.27

FACTOR SCORE HYDROGRAPH FOR YELLOW CREEK NEAR WHITE RIVER

Variable	Factor 1	Factor 2	Communality
Calcium	.937	.115	.900
Chloride	.937	.106	.393
Magnesium	.912	.319	.957
Potassium	.801	.369	.915
Sodium	.927	.154	.903
TDS	.911	.252	.918
Sulfate	.901	.174	.873
Specific conductance	.253	-.838	.961
Percentage Variance explained	43.0%	26.4%	
Cumulative Percent	43.0%	69.4%	

*loadings less than 0.2 omitted.

The dominant controls on surface water quality variation are the source and mechanism of discharge. Base flow is due to the emergence of water from the alluvium where subsurface flow is restricted at the gulches on tract that flow during most of the year. Several springs supply flow to reaches but these flows rapidly infiltrate the alluvium. During periods of intense surface runoff the water in the alluvium is somewhat diluted; however, at the end of surface runoff, discharge from the alluvium is somewhat increased. An additional seasonal variation in alluvial groundwater is the concentration of solids by evapotranspiration during the summer.

CONCLUSIONS

The water quality data collected from springs and seeps indicated the upper oil shale aquifer or the alluvial aquifer as the source. The lower oil shale aquifer was eliminated based on this chemical data. Water from springs and seeps was found to be potable.

The surface stream gaging stations are placed into three groupings based on average concentrations of chemical constituents. They are in order of increasing TDS and flow: Group 1, Rinky Dink Gulch and Stakes Springs Draw; Group 2, Box Elder Gulch, Corral Gulch near the west line and Corral Gulch east of Tract C-a; and Group 3, Yellow Creek.

The interrelationships between constituents and locations were studied in detail. In general, most constituents were found to increase in the downstream direction. The water at the gaging stations in Groups 1 and 2 is generally potable, while the water in Yellow Creek is nonpotable.

The chemical constituents were subdivided statistically into factors, which are groups of constituents that correlate in a similar manner. These factors have been plotted versus time and compared to the surface water hydrology. The resultant correlation allows for the interpretation of some of the mechanisms affecting surface water quality.

CHAPTER 3 - SEDIMENT CHEMISTRY

ABSTRACT

Sediment samples were collected at 35 stations in the vicinity of the Tract C-a during 12 individual surveys over a two-year period (October 1974 to September 1976). Samples were analyzed for aluminum, arsenic, lead, mercury, zinc, volatile solids, Kjeladahl nitrogen and total phosphorus.

The objective of this aspect of the Aquatic Baseline Studies was to determine certain characteristics of stream sediments to provide a measure of pre-development conditions. These baseline levels will be used for comparison with conditions after tract development is initiated.

SEDIMENT ORIGIN AND CHEMISTRY

The data indicate that concentrations for all of the sediment constituents, except mercury, generally decreased from the headwater region (spring brook habitat) to the White River stations. Concentrations of lead and zinc in the sediments of the spring brook stations (Stations 1-18, except 5, 14, Figure 2.2) were generally similar to the levels in the soils of the region. The concentrations of mercury were within the observed range of the soils for all survey dates, except the first two sampling periods (November 1974, January 1975). Levels of volatile solids, total phosphorus and arsenic were generally higher in sediments than in soils, while aluminum levels were significantly lower.

I. Chemistry

The following subsections summarize the sediment chemistry data collected during the 1974-1976 Aquatic Baseline Study. These data are grouped according to habitat type {spring brook (Stations 20, 21, 22); White River backwaters

(Stations 23, 27, 28, 29, 33); and White River open channel (Stations 24, 25, 26, 30, 31, 32, 34, 35, Figure 2.2)

The physical nature of stream sediments in the region varies considerably. The spring brook habitat in the headwater region is dominated by a coarse sand and gravel substrate, with silts, clays, and detritus accumulating during the low flow periods of the year (September-December). The sediments in the Yellow Creek region are somewhat finer than in the spring brook substrates, due largely to finer texture of the soils in the region. The pond habitats (Stations 5, 14, 19) are regions of deposition and generally have much higher levels of silt and clay than the other reaches of the stream. The White River sediments, on the other hand, are more coarse than those in other areas due to higher average stream velocities in the river habitats. The White River sediments are composed predominately of cobble and gravel. Sand, silt, and detritus levels in the sediments increased during low flow periods and tended to be higher in the backwater areas (Stations 23, 27, 28, 29, 33) than in the open channel areas.

Sediment chemical characteristics for the five habitat regions are summarized in Table 2.23. The spatial and temporal variations of sediment chemistry constituents are discussed with regard to available data on stream substrate, as well as stream flow and area soil chemistry.

In general, the concentrations of sediment metals (aluminum, arsenic, lead and zinc) and the organic-related constituents tend to decrease from the headwaters to the White River. Of the metals, only mercury did not follow this trend. Although detailed soil analyses of the headwater region are not available, the pattern of distribution of heavy metals in the sediments indicates that substantial metal deposits are present in the headwater regions. Mineral outcrops of this nature are often found in soils over ore bodies.

The higher levels of organic materials in the sediments of the headwaters (spring brook habitat) result from the elevated organic content of the soils

TABLE 2.23

SUMMARY OF SEDIMENT CHEMISTRY PARAMETERS INCLUDED IN RBOSP AQUATIC BASELINE STUDIES, OCTOBER 1974 - 1976. RESULTS ARE EXPRESSED AS THE MEANS OF AVERAGE CONCENTRATIONS FOR INDIVIDUAL SURVEYS AND THE RANGE FOR ALL SURVEYS.

Habitat	Parameter						
	Aluminum (Al) (ppm)	Arsenic (As) (ppm)	Lead (Pb) (ppm)	Mercury (Hg) (ppb)	Kjeldahl Nitrogen (N) (ppm)	Phosphorus Total (P) (ppm)	Volatile Solids (ppm)
Spring-brook	12,670 (3,200 - 23,500)	16 (2 - 53)	19 (6 - 56)	72[1] (<20 - 887)	1,078 (160 - 7,600)	785 (450 - 1,250)	61,842 (19,750 - 676,000)
Pond	13,368 (6,500 - 27,300)	6 (2 - 14)	14 (4 - 80)	70[1] (<20 - 400)	712 (118 - 1,995)	620 (514 - 960)	41,127 (17,250 - 78,950)
Yellow Creek	8,869 (3,600 - 24,300)	7 (2 - 13)	12 (4 - 50)	142[1] (<20 - 1,240)	481 (118 - 2,017)	608 (462 - 897)	31,896 (11,050 - 96,350)
White River (back channel)	8,500 (4,100 - 17,700)	7 (3 - 20)	29[1] (4 - 45)	100[1] (<20 - 2,300)	629 (170 - 1,850)	574 (361 - 852)	35,555 (9,300 - 75,100)
White River (open channel)	6,431 (3,050 - 20,350)	5 (3 - 10)	15[1] (3 - 760)	149[1] (<20 - 8,800)	490 (82 - 2,300)	600 (358 - 1,025)	26,456 (8,450 - 746,000)

[1]Mean value elevated due to very high value observed during one individual survey.

and the increased productivity of the headwaters region. The transport of detrital material into the streams of the headwaters produces seasonal and spatial patterns of volatile solids, Kjeldahl nitrogen, and total phosphorus in the sediments. Concentrations of these organic-related parameters tend to be highest during the fall and winter and, as previously mentioned, decrease from the headwater region to the White River.

Sediment chemical characteristics are also influenced by hydrologic conditions. The maximum concentrations of the five metals and the three organic-related constituents in the sediments all occurred during relatively low flow periods of the year (September to December). These trends were less evident in the White River, which is a relatively homogeneous environment compared to the other watershed regions.

The maximum concentrations of aluminum (27,300 ppm), arsenic (53 ppm), lead (760 ppm), mercury (8800 ppb), zinc (580 ppm), and Kjeldahl nitrogen (7600 ppm) in the sediments occurred during either November 1974 or January 1975. In general, the levels of these constituents declined over the two-year period of the study.

For the spring brook habitat in the headwater and Tract C-a areas, the highest concentration of metals and organic-related constituents were generally seen at the Corral Gulch stations. Lowest levels of these constituents were generally observed at the stations in Stake Springs Draw.

II. Origin

Extensive evaluation of the soils of Tract C-a and adjacent areas have been conducted by the Gulf Oil Corporation and Standard Oil Company (Indiana) (1976) and the U. S. Geological Survey (Ringrose et al. 1976). Soil chemistry data from the two surveys and the related sediment data for the Tract C-a and headwater region (spring brook habitat) are summarized in Table 2.24.

TABLE 2.24
SUMMARY OF SOIL AND SEDIMENT CHEMISTRY IN THE
VICINITY OF THE TRACT C-a OIL SHALE AREA

	Soils					
	Piceance Creek Basin USGS (1976)		Tract C-a and Adjoining Areas Gulf Oil & Standard Oil (Indiana) 1976		Sediments Springbrook Habitat	
Element	Observed Range	Mean	Observed Range	Mean	Observed Range	Mean
Al (ppm)	34,000 to 78,000	55,000	-	-	3,200 - 23,500	12,620
As (ppm)	<2 to 21	6.4	5 to 40	8.4	2 - 53	16
Hg (ppb)	10 to 220	41	10 to 110	18.8	<20 - 887	72
Pb (ppm)	<3.3 to 56	26	0.7 - 4.0[a]	1.6[a]	6 - 56	16
Zn (ppm)	.45 to 140	80	0.4 - 9.0[b]	1.5[b]	31 - 379	63
Organic matter (ppm)	-	-	1,000 to 218,000	29,000	19,750 - 676,000	61,842
Kjeldahl Nitorgen (ppm)	-	-	-	-	160 - 7,600	1,078
Total Phosphorus (ppm)	95 to 1,549	542	201 - 840	136	450 - 1,250	785

[a] NH_4Acetate Extractable Lead Concentration

[b] DPTA Extractable Zinc (plant available)

Based on these soil data, it appears that the concentrations of lead and zinc in the sediments generally are similar to those found in the soils of the region. However, the range and mean of concentrations for mercury, arsenic, organic matter, and total phosphorus are substantially higher in the sediments than in the soils. All mercury values were within the observed concentration range for the soils, except those reported during the November 1974 and January 1975 surveys.

For these survey periods, sediment mercury concentrations ranging from 200 to 887 ppm were reported in the headwaters and tract region, and concentrations of up to 8800 ppm were observed at the White River stations (Station 25, November 1974). These higher concentrations are probably the result of differences in the analytical techniques used during the initial two survey periods and the period after January 1975.

Higher sediment arsenic levels were generally reported at the stations along Corral Gulch. Corral Gulch is bounded by rock outcrops of the Torriorthents series for much of its length. This formation is reported to have a higher arsenic content than the other major soil series in the region. Also, chemical analysis of processed oil shale yields relatively high arsenic levels. Mineral leaching from either of these sources would account for the higher average arsenic levels in the sediments.

The elevated concentrations of organic matter and total phosphorus in the sediments relative to the levels in the soils of the region are apparently due to the high allochthonous inputs of organic materials from the headwater region and, to a lesser extent, to the autochthonous production within the streams. In general, the pattern of total phosphorus and Kjeldahl nitrogen levels in the sediments closely parallel that of volatile solids.

Aluminum concentrations in the sediments were generally lower than those found in the area soils. This is the result of the relatively low silt and clay content of the sediment. Higher aluminum concentrations in the sediments were

generally found at the pond stations (5, 14, 19) and at the backwater stations on the White River (23, 27, 28, 29, 33). These regions of deposition characteristically have high amounts of silt and clay. The sediments in the pond and backwater habitats also tend to have higher volatile solids and Kjeldahl nitrogen levels than adjoining stations. Total phosphorus was elevated at the pond stations but there was little difference in the phosphorus levels for the two White River habitats.

CHAPTER 4 - AQUATIC BIOLOGY

ABSTRACT

Data on aquatic biota were collected from surface waters of Tract C-a, Yellow Creek and the confluence of Yellow Creek and the White River from October 1974 through September 1976. Samples were collected from thirty-five sampling sites (Figure 2.2). Studies were designed to inventory the aquatic biota and to determine the baseline characteristics of aquatic resources. Aquatic biota studies were conducted in conjunction with extensive physicochemical studies of surface water and groundwater. Species composition, relative abundance and distribution of phytoplankton, zooplankton, macrophytes, periphyton, benthos, and fish were studied. In addition, productivity studies were conducted for periphyton; and age, growth, condition, and reproduction studies were conducted on fishes of the White River and Yellow Creek.

Baseline studies revealed that phytoplankton, zooplankton, and macrophytes play relatively unimportant roles in the aquatic ecosystem of the area. Periphyton are the major primary producers, giving rise to a significant portion of the free-floating planktonic organisms. In the absence of fish, benthic organisms are the primary aquatic consumers on the tract. Fish occur only in Yellow Creek and the White River, because of the ephemeral nature of most on-tract surface water bodies. Distribution of macrophytes is limited to a few pond habitats.

Species composition, diversity and relative abundance for each of the biotic groups were compared for each year of baseline studies and among habitat types. Some fluctuations were noted but, for the most part, these parameters remained stable throughout the study period.

Species composition of phytoplankton was generally similar among habitats (spring brook, pond, creek, river), but the dominant taxa varied.

Rotifers were the most abundant zooplankton organisms and were most numerous in the pond habitats. Protozoans were the second most numerous organisms; highest concentrations occurred in the river habitats. These variations in density reflect the importance of velocity in influencing faunal distribution. Protozoan numbers increased with increased velocity, whereas rotifer numbers declined. Rotifers tend to be destroyed by high turbulence.

Periphyton communities in the pond habitats were more diverse than in the spring brook habitats, were similar to the creek habitats, and were less diverse than in river habitats, as indicated by diversity indices. Mean organic weights were higher in the river habitats than in other areas.

High numbers of benthic taxa were found in the White River and Yellow Creek drainages. Substrate characteristics appeared to be of major importance in determining species diversities. The number of taxa was lower in the creek habitats than in other habitats. The heterogeneous substrate of the river habitats tended to increase benthic diversity. Physicochemical variations appear to influence benthic populations in the various habitat types. Many benthic organisms possess special food-gathering adaptations which allow them to survive in the somewhat adverse conditions of the area.

Only 15 species of fish were collected throughout the two-year baseline study. All specimens were taken from Yellow Creek and White River; no fishes were collected on the tract. Speckled dace was the most abundant species collected. No threatened or endangered species were found. In general, the distribution of fish catches was similar for both years. Most fish were taken from the White River rather than from Yellow Creek. Spawning was earlier in 1976 than in 1975, this was apparently related to a shorter snow melt runoff period in 1976.

The overall objectives of the RBOSP Aquatic Baseline Studies were to characterize the existing aquatic communities on and in the vicinity of Tract C-a and to inventory aquatic habitats which may be affected by oil shale development.

Until the present baseline studies, no detailed studies of the aquatic communities on or near Tract C-a had been undertaken.

The Rio Blanco Oil Shale Project (RBOSP) Aquatic Baseline Studies were intended to perform those environmental studies described in the Federal Register, Volume 39, Number 230, Part 3, Oil Shale Lease Environmental Stipulation and in the Tract C-a Exploratory Plan of May 1974, as conditionally approved in the "Conditions of Approval" agreed upon by letter in August 1974. Specific lease requirements addressed were "The Lessee shall make studies of flora and fauna . . . and also of the Aquatic habitat as far downstream as the Mining Supervisor shall require."

AQUATIC BIOTA

It must be noted at the outset that there are few aquatic habitats on or near Tract C-a and that those which do occur in the area are so limited in variety and extent that their biological resources are virtually unused by man. These aquatic habitats include small spring brooks and seepages and small, marshy ponds. Several miles to the north of the tract are a perennial segment of Yellow Creek (which is a small spring brook) and the White River (which is the only true river habitat in the Piceance Creek basin).

In order to fulfill the program objectives, a total of 35 sampling sites was selected to characterize the aquatic habitats present. Major emphasis was directed toward the two permanent streams, Yellow Creek and the White River, where 18 sampling stations were established. The locations of aquatic sampling stations are shown in Figure 2.2.

Five major habitats were identified for study. They include:

- Spring brooks - Stations 1-4, 6-13, 15-18.
- Ponds - Stations 5, 14, 19.
- Yellow Creek - Stations 20-22.
- White River back channel - Stations 23, 27-29, 33.
- White River open channel - Stations 24-26, 30-32, 34, 35.

Stations 1-4 are located in small, cool springs (rheocrences) with little macrophytic growth. Substrates at these stations are composed of loose aggregations of sand, gravel, and shale fragments covered with periphyton. Other stations considered in the spring brook habitat (Stations 6-13, 15-18) type are similar to Stations 1 through 4 with substrates of gravel, sand, and silt. The chemical content of their waters is also similar to Stations 1 through 4. However, Stations 10, 11, and 16 have been dry throughout the study period. These stations are located in large gulches which are wet only during local precipitation. Stations 6, 12, 15, 17, and 18 were dry during most of the sampling periods. When there was water at these stations, aquatic organisms were present. During the December 1974 sampling, some of the spring brook stations were frozen.

Stations 5, 14, and 19 are classified as ponds. Actually, Stations 5 and 19 are located directly downstream from weed-choked seepage areas with many characteristics of ponds. Station 14 was a pond during 1974-1975 but the dam behind which the pond had formed broke in the early spring of 1976 and the station eventually filled with sand and silt. The faunal composition at Station 14 changed considerably as a result.

Stations 20, 21, and 22 are on Yellow Creek. The stations are very similar to one another and all are within 1000 meters of each other along the lower end of Yellow Creek near its confluence with the White River.

Stations 23, 27-29, and 33 are classified as the back channel stations. They are all located in side channels of the White River where the water velocity is not normally as substantial as in the main river channel. Substrates in this habitat type are very heterogeneous. The major substrate is cobble with rubble and gravel. During low flow periods, siltation was heavy.

Stations 24-26, 30-32, 34, and 35 comprise the open channel habitat type. These stations are in the main channel of the White River.

Sampling techniques were designed to sample phytoplankton, zooplankton, macrophytes, periphyton, benthos, and fishes. Sampling was intensified during warmer

seasons of the year when biological activity was highest. Complete descriptions of sampling methods appear in RBOSP Aquatic Studies Annual Report (1976) and in previous progress reports.

I. PHYTOPLANKTON

The phytoplankton of the study area is derived from both periphytic and truly planktonic sources. Species composition was generally similar among the various habitats studied, but there were distinct differences in the dominant taxa among the various habitats. In all habitats, phytoplankton was secondary to periphyton in autochthonous primary production.

A. Species Composition

During RBOSP aquatic baseline studies, 297 algal taxa were identified in phytoplankton samples collected from the Yellow Creek drainage and from the White River near its confluence with Yellow Creek (see RBOSP Progress Report 10 for complete taxa list). The majority of algal taxa (204) were diatoms (Chrysophyta); 21 taxa belonged to the blue-green algae (Cyanophyta), 54 taxa to the green algae (Chlorophyta), and 3 taxa to the Cryptophyta. The species composition of the phytoplankton was generally similar among the various habitats studied, but there were distinct differences in dominant taxa among the various habitats. These differences reflect the physical and chemical characteristics of the sampling areas as well as in the sources of phytoplankton recruitment.

B. Distribution

1. Spring Brook

Total mean phytoplankton densities at the spring brooks and near Tract C-a were generally higher during the second year of study than during the first. The minimum mean total cell density (628 cells/ml) was observed in October 1974, whereas the highest mean total cell density (9,039 cells/ml) was observed in October 1975 (Table 2.25).

TABLE 2.25
DOMINANT PHYTOPLANKTON TAXA[1] OF SPRING BROOK HABITATS
DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
CYANOPHYTA												
Cyanophyta I	-	-	102	120	86	887	2,705	-	-	-	-	-
CHLOROPHYTA												
Chlorophyta I	19	32	143	114	21	326	667	101	42	147	44	38
CHRYSOPHYTA												
Cyclotella meneghiniana	1	2	-	-	3	9	1,478	5	-	11	-	-
Chrysidiastrum ocellatum	28	427	150	6	3	34	88	84	286	139	22	-
Achnauthes minutissima	183	246	284	182	129	362	482	190	82	543	432	928
Navicula cryptocephala	11	9	85	46	68	125	656	122	61	78	432	291
N. pelliculosa	-	-	89	31	9	4	40	87	426	333	37	44
Mitzschia frustulum	19	11	45	73	26	26	696	157	26	32	65	58
Microftagellate	-	1	108	49	86	1,017	298	143	235	531	121	78
CRYPTOPHYTA												
Cryptomouas erosa	3	1	2	1	8	1	603	1	-	14	-	1
TOTAL (All Species)	628	1,229	1,471	1,185	859	3,883	9,039	1,860	1,349	2,264	1,693	2,005

[1]10 Most Abundant Taxa Over the Study Period

During both 1975 and 1976 at the spring brook stations, mean phytoplankton densities fluctuated between late spring, mid-summer, and late summer. Densities were greatest during the late spring and late summer and lowest during July.

The predominant taxa in the spring brook habitats were diatoms Achnanthes minutissima, Navicula cryptocephala, and Nitzschia frustulum, the chrysophyte Chrysidiastrum ocellatum, and unidentified green and blue-green taxa.

Achnanthes minutissima was also the dominant algal taxon in the periphyton communities of the spring brook habitats. Navicula cryptocephala was also very common in the periphyton of these habitats during the study period. Both of these diatoms are indicators of alkaline waters (Lowe 1974). The commonality of species composition and of predominant species in the phytoplankton and periphyton and the relatively low densities of phytoplankton indicate that the planktonic algae of these habitats are generally derived from the periphytic algae.

2. Ponds

Total mean phytoplankton densities in the pond habitats on and near Tract C-a were lower than in any other habitats found, except in the White River open channel areas. These consistently low densities in the pond habitats are likely due to reduced scouring of the periphytic algae in the pond areas. The total mean phytoplankton densities in the ponds were generally higher during the second year of study; the minimum mean total density (138 cells/ml) was observed in December 1974, whereas the highest mean total cell density (3,555 cells/ml) was observed in April 1976 (Table 2.26).

During both 1975 and 1976, seasonal phytoplankton maxima were observed in April in the pond habitats. The predominant planktonic algal taxa of the ponds during the study period were the diatoms Cyclotella meneghiniana, Achnanthes minutissima, Navicula cryptocephala, Navicula pelliculosa,

TABLE 2.26
DOMINANT PHYTOPLANKTON TAXA[1] OF POND HABITATS
DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976.

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
CHLOROPHYTA												
Quadrigula lacustris	-	-	-	-	-	-	-	-	-	792	-	-
Chlorophyta I	14	10	206	70	20	31	92	69	61	90	45	24
CHRYSOPHYTA												
Cyclotella Meneghiniana	3	2	2	13	8	11	288	8	19	187	13	5
Achnanthes minutissima	169	29	112	145	21	28	427	24	75	126	25	8
Navicula cryptocephala	2	1	113	14	26	16	39	35	249	96	34	6
N. pelliculosa	-	1	270	1	3	-	43	3	622	27	12	9
Nitzschia acicularis	2	-	4	6	154	29	124	50	34	7	2	14
N. frustulum	17	9	295	36	12	84	29	35	147	31	23	6
N. Holsatica	-	-	-	-	16	50	35	40	320	18	9	22
Microflagellate	-	8	108	79	83	52	248	50	1,102	326	104	71
TOTAL (All Species)	375	138	2,230	806	808	716	2,350	538	3,555	2,932	538	241

[1]10 Most Abundant Taxa Over the Study Period.

Nitzschia frustulum, Nitzschia holsatica, an unidentified green alga, and unidentified microflagellates. Most of these taxa were also abundant in the periphyton, indicating the derivation of most pond phytoplankton is periphytic algae. Cyclotella meneghiniana, however, is characterized as tychoplanktonic, euplanktonic, or periphytic (Lowe 1974) and it is likely that this species is truly planktonic in these pond habitats.

3. Yellow Creek

Total mean phytoplankton densities in Yellow Creek were generally higher than in any other habitat included in the RBOSP aquatic baseline study. These generally higher densities are related to the larger number of sources of recruitment of periphytic algae as well as different chemical and nutrient conditions in Yellow Creek. Mean phytoplankton densities were generally higher during the second year of study; the minimum mean density (557 cells/ml) was observed in August 1975, whereas maximum mean density (22,331 cells/ml) was observed in April 1976 (Table 2.27).

During both 1975 and 1976, seasonal phytoplankton maxima were observed in the spring. The predominant algal taxa in the phytoplankton of Yellow Creek during the baseline study were the diatoms Cyclotella meneghiniana, Nitzschia capitellata, and Surirella ovata; and unidentified microflagellates. Cyclotella meneghiniana and Surirella ovata were also among the predominant algal taxa observed in the periphyton. During the spring phytoplankton maxima in 1975 and 1976, Surirella ovata was the most abundant species in Yellow Creek.

The relatively great amount of usage of Yellow Creek by livestock and the large number of slack water areas provide greater opportunity for the recruitment of periphytic algal and for development of planktonic taxa. Thus, Yellow Creek generally maintains a greater phytoplankton abundance than do the other habitats of the study area.

TABLE 2.27
DOMINANT PHYTOPLANKTON TAXA[1] OF YELLOW CREEK HABITATS
DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
CHLOROPHYTA												
Chlorophyta I	25	16	111	71	22	-	46	29	221	41	57	61
Chlorophyta II	-	-	-	736	-	-	-	-	-	-	-	-
CHRYSOPHYTA												
Cyclotella meneghiniana	202	497	297	8,200	715	180	371	168	63	1,259	530	574
Fragilaria vaucheriae	1	15	73	-	-	1	2	2	518	1	1	2
Synedra amphicephala	3	9	20	-	5	-	56	29	878	-	1	-
Achnanthes minutissima	99	59	51	254	10	23	104	40	9	4	6	3
Nitzschia capitellata	-	-	-	-	37	43	25	13	5,612	5	23	52
N. holsatica	-	-	-	-	44	55	98	345	27	26	86	844
Surirella ovata	-	-	1,531	34	1	-	4	16	12,537	16	12	66
Microflagellate	-	-	218	104	109	22	122	30	977	149	146	99
TOTAL (All Species)	984	846	3,130	9,875	1,223	557	1,589	1,016	22,331	1,714	1,526	2,366

[1] 10 Most Abundant Taxa Over the Study Period.

4. White River

Phytoplankton species composition and abundance was very similar in the open and back channel habitats of the White River. This similarity is expected since the paucity of slack-water areas and swift currents in the White River habitats reduce the ability of truly planktonic species to develop. The minimum mean total density (401 cells/ml) was observed in the back channel habitats in August 1976, whereas the maximum mean total density (2,150 cells/ml) was observed in the back channel habitats in April 1976 (Table 2.27).

In both 1975 and 1976, phytoplankton maxima were observed in the White River open and back channel habitats in winter and spring (Tables 2.28 and 2.29). The predominant algal taxa in both habitats were the diatoms Diatoma vulgare, Navicula cryptocephala, and Navicula viridula. The phytoplankton of the White River habitats contained a mixture of algae derived from both periphytic and planktonic sources. Phytoplankton composition and dominant species were different from the phytoplankton in Yellow Creek or in the spring brooks or ponds. Phytoplankton densities were generally low in the White River. It is evident from the similarity in dominant species in the phytoplankton and periphyton of the White River that the planktonic algae are derived from periphytic algae and thus represent a secondary source of productivity.

In most of the aquatic habitats studied, the major source of phytoplankton was the periphytic algae. Thus, in the aquatic habitats on and near Tract C-a, phytoplankton constitutes a secondary source of autochothonous primary production.

TABLE 2.28

DOMINANT PHYTOPLANKTON TAXA[1] OF OPEN CHANNEL HABITATS
DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976.

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
CHLOROPHYTA												
Chlorophyta 1	16	33	150	99	16	4	40	48	55	70	43	30
CHRYSOPHYTA												
Thalassiosira fluviatilis	-	13	247	27	1	3	20	4	20	1	1	-
Diatoma vulgare	51	621	28	4	10	5	29	152	38	6	3	-
Navicula Cryptocephala	17	41	121	21	23	24	29	56	107	137	44	14
N. viridula	2	14	361	16	26	21	21	87	553	114	16	4
Gomphonema olivaceum	26	27	52	1	17	9	16	16	207	95	30	21
G. ventricosum	15	55	242	4	2	15	13	46	14	4	1	1
Epithemia sorex	59	44	27	2	1	329	36	16	23	3	21	21
Nitzschia frustulum	25	72	50	29	10	74	33	13	25	21	14	14
Microflagellate	-	-	13	29	62	33	43	12	68	33	59	41
TOTAL (All Species)	458	1,550	1,990	727	602	775	529	670	1,741	1,154	715	409

[1] 10 Most Abundant Taxa Over the Study Period.

TABLE 2.29

DOMINANT PHYTOPLANKTON TAXA[1] OF BACK CHANNEL HABITATS DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976.

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
CHLOROPHYTA												
Chlorophyta I	16	33	150	99	16	4	40	48	55	70	43	23
CHRYSOPHYTA												
Diatoma vulgare	51	621	28	4	10	5	29	152	38	6	3	-
Navicula cryptocephala	17	41	121	21	23	24	29	56	107	137	44	14
N. viridula	2	14	361	16	26	21	21	87	553	114	16	9
Gomphonema olivaceum	26	27	52	1	17	9	16	16	207	95	30	15
Epithemia Sorex	59	44	27	2	1	329	36	16	23	3	21	27
Nitzschia capitellata	-	-	-	-	15	9	1	1	22	30	46	18
N. frustulum	25	72	50	29	10	74	33	13	25	21	14	12
Surirella ovata	2	14	51	4	3	2	65	11	419	70	484	1
Microflagellate	-	-	13	29	62	33	43	12	68	33	59	46
TOTAL (All Species)	526	1,549	1,662	936	512	921	491	610	2,150	1,034	909	401

[1]10 Most Abundant Taxa Over the Study Period.

II. ZOOPLANKTON

The zooplankton fauna in the RBOSP study area is composed mostly of cosmopolitan species which occur in similar habitats throughout the United States. The habitats sampled on or near Tract C-a include: a river (White River), a slow meandering creek (Yellow Creek), several ponds, and several spring brooks. The fauna consists predominantly of benthic and littoral forms.

A. Species Diversity

During the two-year RBOSP baseline study, 151 taxa were identified in zooplankton samples collected in the Yellow Creek drainage system and from the White River near its confluence with Yellow Creek. A complete list of these taxa appears in RBOSP Progress Report 10. The list includes 63 Protozoa, 56 Rotifera, 17 Cladocera, 14 Copepoda and one Amphipoda taxa. Unidentified species of Gastrotricha, Tardigrada and Ostracoda were also observed.

Most protozoan taxa identified were rhizopods. Ciliates were sometimes quite diverse; however, most were unidentifiable due to their preserved condition. Many illoricate bdelloids and monogonont rotifers were encountered; however, these forms contract and become distorted when preserved, usually making their identification below the bdelloid or monogonont level nearly impossible.

Most identifiable rotifers were littoral although a few limnetic forms were observed in White River samples. Only a few limnetic Crustacea were found. Almost all species collected were typical of littoral habitats or, in the case of ostracods and harpacticoids, of benthic habitats.

B. Distribution and Abundance

1. Spring Brooks

Densities of dominant zooplankton species from all spring brook habitats ranged from a minimum of 2,991/m^3 in April 1976 to a maximum of 39,432/m^3 in June 1975 (Table 2.30). Densities were generally highest in the summer and fall.

TABLE 2.30
DOMINANT ZOOPLANKTON SPECIES OF SPRING BROOK HABITATS, RBOSP
MEAN DENSITIES (ORGANISMA/M^3) OF ALL SPRING BROOK HABITATS

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
PROTOZOA[a]												
Centropyxis aculeata	1400	1820	1063	1000	500	90	240	127	110	83	238	238
Centropyxis constricta	3813	2320	300	9156	1127	880	1370	364	780	1250	2788	1388
Unidentified ciliates	38	80	88	178	64	300	500	600	100	108	325	63
Peritrich ciliates	4750	220	750	367	245	230	280	500	0	17	250	88
Total Protozoa	11050	4660	3063	13989	2345	1710	4200	2236	1160	1683	4563	2413
ROTIFERA[a]												
Bdelloids (unidentified)	1775	60	3500	23000	845	880	1860	473	520	1883	400	1475
Cephalodella volvocicola	0	0	0	0	0	0	0	436	0	225	50	388
Unidentified monogononts	1000	240	1025	33	655	780	1870	164	90	133	225	675
Notholca acuminata	25	260	0	144	55	0	0	64	210	3375	13	0
Total Rotifera	5963	1380	5600	24067	1873	1890	4460	1227	910	7117	925	2863
CRUSTACEA[b]												
Ostracods	227	151	54	223	512	276	267	45	115	361	764	2556
Copepod nauplii	1850	1040	313	1033	536	150	750	455	650	625	363	1063
Bryocamptus hiemalis	207	303	75	97	34	51	57	46	150	260	87	136
Total Crustacea	2308	1526	447	1362	1086	489	1150	547	916	1257	1273	3804
TOTAL (All Species)	19328	7607	9134	39432	5305	4096	9815	4024	2991	10069	6776	9092

[a] Species which composed 10% or more of the total on at least one date

[b] Species which composed 1% or more of the total on at least one date.

Protozoa populations were dominated by Centropyxis constricta and peritrich ciliates throughout the study period. These organisms are benthic or periphytic in nature and their occurrence in the plankton probably reflects disturbance of the substrate, (e.g. cattle walking in the stream).

Rotifers exhibited definite seasonal fluctuations in abundance. Greatest densities occurred in June of each year. The maximum density in June 1975 (24,000/m^3) was three times that of June 1976. Dominant taxa at the spring brook stations included bdelloids, monogononts, and, less often, Cephalodella volvocicola and Notholca acuminata.

The crustacean fauna of the spring brooks was composed almost entirely of benthic ostracods and harpacticoids and their nauplii. Neither the ostracods nor the harpacticoids exhibited any definite seasonal distribution patterns. Other Crustacea were sparse and their occurrence was related to the nature of the area sampled. For example, littoral rotifers and Crustacens were often found in the headwaters of spring brooks where large beds of macrophytes occurred. Several spring brook stations (Station 15, 17, and 18) were dry much of the year. When wet, these stations consisted of a series of small pools which often supported large populations of ciliated protozoan, typical of the spring brook stations.

2. Ponds

Zooplankton were generally more abundant in pond habitats than in spring brook habitats. Densities in ponds ranged from 2,952/m^3 in April 1975 to well over 160,000/m^3 in June 1976 (Table 2.31).

Protozoa were of relatively less importance in the pond habitats than in the spring brooks. Peritrich ciliates, predominantly Vorticella sp., were the dominant protozoans.

Rotifers were frequently the major components of the pond plankton. Rotifer densities ranged from less than 2,000/m^3 in April 1975 to more than 158,000/m^3 in June 1976. Their abundance was greatly affected by season, with low numbers in the early spring and maximum numbers in summer. The maximum densities during

TABLE 2.31
DOMINANT ZOOPLANKTON SPECIES OF POND HABITATS, RBOSP
MEAN DENSITIES (ORGANISM /M³) FOR ALL POND HABITATS

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
PROTOZOA[a]												
Peritrich ciliates	5233	67	700	633	833	67	100	200	1167	67	767	267
Total Protozoa	7100	1100	1167	2200	1300	600	567	1367	2800	1133	2633	1767
ROTIFERA[a]												
Bdelloids (unidentified)	633	14300	467	5267	100	1300	8533	200	2267	1400	4533	967
Euclanis dilatata	0	0	0	1800	1333	1333	2400	100	0	2167	333	200
Lepadella patella	1100	167	0	10567	1433	633	3867	33	533	12000	867	767
Unidentified monogononts	867	100	367	6533	6233	4267	400	200	667	933	67	367
Notholca acuminata	6633	667	367	15733	1567	33	400	3100	15233	97867	233	100
Notholca squamula	1100	67	133	11567	133	0	67	267	467	41867	33	67
Total Rotifer	15867	16400	1567	65367	11033	9400	19167	3933	19400	158633	17633	3800
CRUSTACEA[b]												
Alona circumfimbriatus	120	0	2	0	62	1328	188	12	3	8	503	453
Ceriodaphnia quadrangula												
Chydorus sphaericus	32	0	3	157	47	32	145	28	3	3	90	328
Pleuroxus aduncus	280	0	0	17	20	178	63	0	2	2	9218	5320
Ostracoda	48	7	22	482	1355	117	27	32	27	462	39948	718
Copepod nauplii	333	0	167	0	900	667	2433	67	133	467	567	67
Cyclopoid copepodites	635	12	0	77	207	378	627	5	8	32	492	17
Eucyclops agilis	46	12	10	52	143	80	33	13	2	18	67	12
Total Crustacea	2765	33	217	853	2815	4820	3633	185	237	1030	51085	6933
TOTAL (All Species)	25732	17535	2952	68420	15148	14820	23697	5487	22438	160797	71352	12500

[a]Species which composed 10% or more of the total on at least one date.

[b]Species which composed 1% or more of the total on at least one date.

both baseline years occurred in June, when densities reached 65,367 and 158,633/m^3 in 1975 and 1976, respectively. Notholca acuminata and Notholca squamula were the major components of the rotifer fauna during months of maximum densities. Numbers of rotifers decreased somewhat after June 1975 and rose again in October 1975. The increase was attributed to the presences of large numbers of bdelloid rotifers. Other rotifers abundant in the pond habitats included Euchlanis dilatata, Lepadella patella, and unidentified monogononts. A large variety of other rotifers, predominantly littoral forms, occurred in low numbers in the ponds. These included Lecane spp., Monostyla spp., Mytilina ventralis, Trichotria pocillum, Colurella adriatica, and Cephalodella spp.

A relatively diverse and abundant crustacean fauna occured at the pond stations. The species found were typical of North American pond habitats. Crustacean densities ranged from a minimum of 33/m^3 (predominantly Eucyclops agilis) in December 1974 to a maximum of more than 51,000/m^3 (predominantly ostracods in July 1976. Seasonal maximum densities of 4,820 and 51,085/m^3, occurred in August of 1975 and 1976, respectively. Dominant taxa in these months included Alona circumfimbriata, Pleuroxus aduncus, and cyclopoid copepodites.

The dam at Station 14, one of the pond stations, was washed out during the spring of 1976, resulting in a major alteration of the habitat. The area and depth of the pond were greatly reduced. For this reason, most of the 1976 samples were taken near the inlet for the lack of other suitable sampling areas. Large numbers of Ceriodaphnia quadrangula had been encountered at Station 14 in 1975, but few were found in 1976. The change in habitat at Station 14 may explain the rareness of this organism during 1976. Large numbers of ostracods (39,948/m^3) occurred in July 1976, probably related to the high densities of filamentous algal mats near that station.

Eucyclops agilis was the dominant copepod at the pond stations. It was most numerous in summer and early fall. Peak densities for both copepod nauplii and cyclopoid copepodites followed those of the adults. Several other littoral Crustacea, including Cyclops vernalis, Eucyclops speratus, Macrocyclops albidus, Chydorus sphaericus, and Simocephalus vetulus, were common at one or more of the pond habitats.

3. Yellow Creek

A relatively high diversity of zooplankton occurred in Yellow Creek Stations. Species composition was similar to that of the pond habitats. Densities ranged from approximately 1,400/m^3 in November 1975 and April 1976 to more than 20,000/m^3 in July 1976 (Table 2.32). As in the spring brooks and ponds, highest densities occurred in summer and early fall. Rhizopods dominated the Protozoa at the creek stations. Dominant taxa included Centropyxis aculeata, Centropyxis constricta, and Difflugia sp. Protozoan densities varied from as few as 600/m^3 in August 1975 to more than 6,000/m^3 in April 1975 and August 1976. These high values probably reflect increased numbers of rhizopods and peritrichs following disturbance of the stream substrate in April by the upstream crossing of a herd of sheep and the influence of several hundred grazing cattle in August.

Rotifer populations peaked later in the creek habitats than in the pond habitats. Dominant species included Brachyonus quadridentatus, Lecane luna, and Tripleuchlanis plicata, all of which numbered over 2,000/m^3 in July 1976. Other common species in Yellow Creek included Cephalodella spp., Lepadella patella, Monostyla spp., Notholca spp., and unidentified monogononts.

The crustacean fauna of the creek habitats was basically the same as that of the ponds. Maximum densities, (more than 6000/m^3 in both August 1976 and July 1976) occurred in the summer. Although the taxa found in 1975 and 1976 were similar, species abundance varied. During the summer of 1975 the crustacean fauna was dominated by Pleuroxus aduncus, Simocephalus vetulus, Eucyclops agilis, and immature cyclopoids. In the summer of 1976, Pleuroxus aduncus and Eucyclops agilis occurred in relatively low numbers and Simocephalus vetulus was absent. Ostracods were the dominant crustaceans. The relatively low numbers of cladocerans and cyclopoids in (1976) were possibly related to continued disturbances by cattle, resulting in increased turbidity and organic loads in the water of the creek.

Additional crustaceans found in the Creek habitats during the two-year study include Cyclops vernalis, Cyclops varicans rubellus, Eucyclops speratus, Alona circumfimbriata, Chydorus sphaericus, and Ceriodaphnia quadrangula.

TABLE 2.32
DOMINANT ZOOPLANKTON SPECIES IN YELLOW CREEK HABITATS,
RBOSP MEAN DENSITIES (ORGANISMA/M^3) FOR ALL YELLOW CREEK HABITATS

	1974		1975						1976			
	Oct.	Dec.	Apr.	June	July	Aug.	Oct.	Nov.	Apr.	June	July	Aug.
PROTOZOA a												
Centropyxis aculeata	1167	1500	5267	33	167	0	100	33	33	67	0	33
Centropyxis constricta	300	233	0	267	1367	67	1867	567	467	133	167	4133
Unidentified ciliates	167	67	67	33	0	33	567	333	167	0	0	1500
Difflugia spp.	33	0	400	67	33	467	200	33	0	1967	33	67
Heleopera sp.	0	0	0	300	0	0	0	0	0	0	0	0
Peritrich ciliates	233	0	600	33	0	0	0	0	33	467	0	1000
Total Protozoa	1933	1933	6367	767	1733	600	3000	967	767	2633	233	6967
ROTIFERA a												
Brachionus quadridentatus	33	0	0	0	0	0	0	0	0	467	4867	633
Cephalodella sp.	700	0	0	0	0	0	0	0	0	0	0	0
Cephalodella volvocicola	0	0	0	0	0	0	33	0	67	1267	167	0
Colurella adriatica	0	0	100	400	0	2300	100	67	0	6167	0	100
Lecane luna	0	0	0	133	0	733	0	0	0	0	2067	667
Lepadella patella	300	200	0	100	0	0	133	0	0	1600	33	0
Unidentified monogononts	267	100	67	67	100	367	100	67	233	33	567	133
Notholca acuminata	3967	567	33	333	0	0	333	67	100	433	0	0
Triplenchlanis plicata	0	0	0	0	0	0	0	0	0	0	3433	300
Total Rotifera	5867	2200	400	1267	133	4033	900	233	467	11133	14433	2733
CRUSTACEA b												
Alona circumfimbriata	6	0	0	0	2	15	23	0	0	0	195	288
Pleuroxus aduncus	0	2	0	0	200	3492	78	2	0	0	143	40
Simocephalus vetulus	4	0	0	0	12	547	10	0	0	0	0	0
Ostracods	4	5	28	28	3	15	3	0	18	78	3728	122
Copepod nauplii	100	167	100	233	233	1067	900	67	167	633	1333	33
Cyclopoid copepodites	20	7	32	32	190	403	412	65	0	82	640	2
Eucyclops agilis	12	0	12	18	722	1053	297	27	5	12	3	3
Total crustacea	152	182	183	320	1375	6595	1725	160	190	837	6117	488
Totals (ALL SPECIES)	7952	4315	6940	2353	3242	11228	5625	1360	1423	14603	20783	10355

a. Species which composed 10% or more of the total on at least one date.

b. Species which composed 1% or more of the total on at least one date.

4. White River

Zooplankton diversity and abundance were almost identical for White River back channel and open channel habitats. Combined mean zooplankton densities for each habitat ranged from 4,500/m^3 in August 1976 to more than 22,000/m^3 in August 1975 (Tables 2.33 and 2.34).

Protozoa in the White River were dominated by Centropyxis spp. and peritrich ciliates throughout the study period. Fluctuations in protozoan population densities could not be correlated with seasons because of the impossibility of separating seasonal trends from the effects of substrate disturbances.

Rotifers were not as abundant in the river habitats as they were in spring brook, pond, or creek habitats. Rotifer densities were generally greatest in the summer months; however, the highest densities (6,800 and 7,075/m^3) occurred in December 1975 due to the enormous numbers of unidentified monogononts present in this month. The rotifer fauna of the river was similar to that of the Yellow Creek drainage system. In addition, on rare occurrences, limnetic species, such as Keratella cochlearis, were occasionally found. These species possibly were recruited from the few lakes and larger ponds located upstream.

The crustacean fauna of the river were extremely sparse and were composed predominantly of copepod nauplii throughout the study period. Mean monthly densities were usually less than 200/m^3, although densities in excess of 600/m^3 were observed in June 1976 in both back and open channel habitats.

5. All Habitats

A comparison of the relative abundance of major zooplankton groups in each habitat is presented in Table 2.35. Protozoa were a much larger component of the fauna in the river than in the other habitats. Also, mean densities of protozoans were slightly higher in spring brooks than in the pond or creek habitats. These trends are related to the abundance of rhizopod protozoans, whose presence in the plankton is controlled at least partially by substrate disturbances and the velocity of the stream.

TABLE 2.33
DOMINANT ZOOPLANKTON SPECIES AT BACK CHANNEL RIVER HABITATS, RBOSP
MEAN DENSITIES (ORGANISMA/M^3) OF ALL BACK CHANNEL RIVER HABITATS

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
PROTOZOA [a]												
Centropyxis aculeata	6640	6050	3440	1300	360	6200	1600	480	580	225	380	600
Centropyxis arcelloides	0	0	80	1340	320	340	180	160	320	175	2560	600
Centropyxis constricta	280	200	760	2520	920	8940	680	800	3760	825	320	640
Centropyxis ecornis	0	0	0				660	200	160	0	100	320
Unidentified ciliates	80	400	180	40	60	360	800	640	220	100	20	0
Peritrich ciliates	3620	2400	4420	140	660	1260	720	2120	3440	4725	1540	380
Total Protozoa	10960	9300	10500	5520	2580	17760	4940	4500	8580	6150	5040	2700
ROTIFERA [a]												
Euchlanis dilatata	0	0	0	40	1040	80	0	0	0	75	0	60
Lepadella patella	680	300	0	0	280	320	180	40	0	300	740	220
Unidentified monogononts	160	6000	1060	160	3220	2620	1020	1100	1080	3300	140	220
Total Rotifera	2860	6800	2880	800	5860	4400	1980	1580	2500	6400	2120	900
CRUSTACEA [b]												
Copepod nauplii	40	0	60	200	220	220	260	100	220	475	20	0
Total Crustacea	44	38	85	218	244	222	366	113	231	619	108	5
TOTAL ALL SPECIES	13864	16138	13469	6538	8704	22383	7286	6193	11319	13203	7278	3607

a. Species which composed 10% or more of the total on at least one date.

b. Species which composed 1% or more of the total on at least one date.

TABLE 2.34
DOMINANT ZOOPLANKTON SPECIES AT OPEN CHANNEL RIVER HABITATS, RBOSP
MEAN DENSITIES (ORGANISMA/M^3) OF ALL OPEN CHANNEL RIVER HABITATS

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
PROTOZOA [a]												
Centropyxis aculeata	8238	5400	4075	2113	350	6013	1363	525	800	320	688	613
Centropyxis arcelloides	0	0	50	1388	500	525	263	100	225	180	2363	325
Centropyxis constricta	850	425	875	4313	1450	8288	1088	638	2988	1000	738	400
Centropyxis ecornis	0	0	0	0	0	0	825	263	150	0	225	600
Peritrich ciliates	2088	5668	2363	163	663	2800	900	2362	3700	4160	1000	513
Total Protozoa	11450	12325	9100	8501	3225	18925	5313	4450	8238	5860	5200	2725
ROTIFERA [a]												
Unidentified monogononts	100	4819	888	88	3213	2788	875	1750	1213	3040	25	563
Total Rotifera	2838	7075	2213	750	4663	4438	1700	2288	2988	6080	638	1575
CRUSTACEA [b]												
Copepod nauplii	50	75	63	150	363	75	13	38	163	560	0	38
Total Crustacea	54	88	70	169	453	81	25	39	169	668	11	42
TOTAL ALL SPECIES	14341	19489	11384	9432	8378	23444	7038	6776	11401	12635	5855	4343

a. Species which composed 10% or more of the total on at least one date.

b. Species which composed 1% or more of the total on at least one date.

TABLE 2.35
COMPARISON OF ZOOPLANKTON DENSITIES (ORGANISM/M^3) AT FIVE HABITATS.
DENSITIES ARE MEANS FOR ALL SAMPLING DATES (OCT '74-AUG '76).

	Spring Brooks	Ponds	Yellow Creek	White River Back Channel	White River Open Channel
PROTOZOA	4423	1978	2325	7378	7943
ROTIFERA	4856	28517	3650	3257	3104
CLADOCERA	11	1854	423	6	9
CYCLOPOIDA	11	266	347	18	11
HARPACTICOIDA	127	7	0	4	3
OSTRACODA	463	3604	336	9	3

The importance of velocity is reflected by results of the present study. Protozoa densities increased as the stream velocities increased: River > Spring Brook > Creek > Pond.

The rotifer fauna consisted almost entirely of bdelloids and cosmopolitan littoral monogonont rotifers. Since alkaline water (pH7) is generally a requirement of the cosmopolitan rotifer species, their presence throughout the study area is expected. The low densities present in the White River reflect the nature of the river's drainage system. The rotifer fauna of the major rivers in North America have generally included large numbers of limnetic forms such as Keratella and Polyarthra which are recruited from impoundments along the river's drainage. The rarity of these forms in the White River is to be expected as there are few upstream impoundments and the high velocity and shallowness of the river tend to destroy the few organisms that may enter the river.

Highest densities of rotifers occurred in the pond habitats where conditions were ideal for the development of a large littoral fauna. Abundant submerged vegetation, such as Chara (Station 19) and Zannichellia palustris (Station 14), provide ample substrate for these forms.

The distribution and abundance of Cladocera and Cyclopoida were similar to those of the Rotifera. Their rarity in the river and spring brooks and their abundance at the creek and pond stations are controlled by similar factors such as abundance of macrophytes and stream velocity. Harpacticoid copepods were important only in the spring brook plankton. These forms are benthic, living on and in gravel substrates. In the spring brooks, harpacticoid abundance did not fluctuate seasonally, possibly because of the year-round constancy of water temperatures.

Ostracods were very poorly represented in the river habitats. The large populations in the spring brook and creek samples consisted predominantly of young ostracods which were small enough to be suspended in the water of the small streams. On one occasion at Station 14 in July 1976, ostracods occurred in high numbers in the pond plankton.

The majority of the crustacean species occurring in the Yellow Creek drainage system are cosmopolitan in their distribution and many have often been collected in waters of higher salinities than occur in Yellow Creek. As with the Protozoa and Rotifera, most of the Crustacea collected are characteristic of littoral habitats throughout North America.

III. MACROPHYTES

In general, aquatic macrophytes did not comprise a major component of the aquatic ecosystems on or near Tract C-a, although macrophytes were found in some of the pond and spring brook habitats. Relative abundance of aquatic macrophytes varied greatly but was generally scattered to moderate, according to the ranking system of Jessen and Lound (1962). In both 1975 and 1976, macrophytes were most abundant during the late summer sampling periods (Table 2.36).

The aquatic macrophytes found on or near Tract C-a are emergents and/or are plants typical of moist to wet alkaline habitats. Plants more typical of alkaline ponds include bayonet grass, stonework, shore crowfoot, and horned pondweed. Although many of the other species (e.g., American speedwell, three-square and manna-grass) may occur in wet alkaline habitats, they are more cosmopolitan and occur in a variety of paludal habitats.

A list of macrophytes encountered during the survey appears below.

Scientific name [a]	Colloquial name
Chara kieneri	Stonewort
Clyceria sp.	Manna Grass
Hippuris vulgaris	Mare's-tail
Potamogeton cf. *foliosus*	Pondweed
Ranunculus cymbalaria	Shore Crowfoot
Ranunculus natans	Water Crowfoot
Rorippa nasturtium-aquaticum	Watercress
Scirpus americanus	Three-square
Scirpus paludosus	Bayonet-grass
Veronica americana	American Speedwell
Zannichellia palustris	Horned Pondweed

[a] Nomenclature according to Harrington, H.D. (1964)

TABLE 2.36
RELATIVE ABUNDANCE OF MACROPHYTES AT AQUATIC SAMPLING STATIONS DURING RBOSP AQUATIC BASELINE STUDIES, OCTOBER-NOVEMBER 1974 TO AUGUST-SEPTEMBER 1975.

Station	1974	1975				
	Oct.-Nov.	Dec.-Jan.	Apr.	May-Jn.	Jy.-Aug.	Aug.-Sep.
1				Watercress-1[a]		American Speedwell-1
2			Watercress		American Speedwell-1 Shore Crowfoot-2	American Speedwell-1
3					American Speedwell-2	Shore Crowfoot-2
4						American Speedwell-1
5		Unknown Sedge		American Speedwell-3 Shore Crowfoot- Watercress-1 Manna Grass-3	Horned Pondweed Shore Crowfoot-1 Watercress- Water Crowfoot-2	American Speedwell-2 Shore Crowfoot-4 Watercress-2
7						Shore Crowfoot-2
8		Pondweed Watercress	Unknown Grass Watercress	Unknown Grass-3 Watercress-2		
9	Horned Pondweed					Shore Crowfoot-1
10	Watercress Mares Tail					
14	Stonewort		Horned Pondweed	Horned Pondweed-3	Horned Pondweed-4	Horned Pondweed-5
19			Stonewort (dead)	Stonewort-5		Stonewort-5 Shore Crowfoot-2 Horned Pondweed-2 Three-square
20				Horned Pondweed-4		Horned Pondweed-4 Three-square Bayonet-grass-3
21						Horned Pondweed-4 Three-square-3 Bayonet-grass-3

TABLE 2.36 continued

Station	1975		1976			
	Oct.	Nov.-Dec.	Apr.[b]	May-Jn.	Jy	Aug.-Sep.
1					Watercress-1	
2	American Speedwell-1	American Speedwell-2		Watercress-2	Watercress-1	Shore Crowfoot-1
4				Watercress-1	Watercress-1	Shore Crowfoot-1
5	Watercress-5 Shore Crowfoot-2			Watercress-1	Shore Crowfoot-2 Stonewort-2 Horned Pondweed-2 Cattail-2	Marsh Marigold-3
						Shore Crowfoot-1 Watercress-1
14	Horned Pondweed-5			Horned Pondweed-2	Horned Pondweed-5	Horned Pondweed-4 Sedges-1
19	Shore Crowfoot-1			Stonewort-1 Horned Pondweed-5	Horned Pondweed-2	Shore Crowfoot-1 Rushes-5

[a]Number indicates relative abundance of plants as provided in Jessen and Lound, 1962.

5 (most abundant)
4 heavy growth
3 moderate growth
2 scattered growth
1 (least abundant)

[b] No macrophytes were observed during this sampling period.

IV. PERIPHYTON

A. Species Composition

A total of 197 algal taxa was found in periphyton samples from the Yellow Creek drainage system and from the White River near its confluence with Yellow Creek. (A complete listing of Periphyton taxa identified during the study appears in RBOSP Progress Report 10). Ten taxa were identified as filamentous blue-green algae (Cyanophyta) and 16 taxa were identified as green algae (Chlorophyta). Most filamentous algae were unidentifiable beyond genus because of cell plasmolysis during sample preservation and preparation. One monoflagellated Chrysophyta (yellow brown alga) species was found during the study. The remaining 180 taxa were diatoms (Chrysophyta) which dominated the periphyton communities during the two-year study.

B. Distribution and Abundance in Natural Habitats

1. Spring Brooks

Standing crops of periphyton communities were measured in terms of total cell counts, organic weight (ash-free dry weight), and chlorophyll a.

The highest periphyton standing crops of the spring brook habitats occurred in the early winter during both years; total mean cell densities showed a peak of 8,856 cells/mm^2 in the winter of the first year and a second larger peak of 26,974 cells/mm^2 in the winter of the second year (Table 2.37). Organic weights appeared to peak in the early winter of each year (Table 2.38). The highest mean chlorophyll a value recorded during the first year (1.5 mg/m^2) occurred in August, whereas the highest mean value (5.2 mg/m^2) during the second year was observed in the spring (Table 2.39).

Maximum Shannon diversity indices (1.86 and 2.16) occurred during July of each year; the lowest indices occurred in the early spring of each year when cell densities were moderately high (Table 2.40). Mean number of species

TABLE 2.37

DOMINANT PERIPHYTON TAXA[a] OF SPRING BROOK HABITATS DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976.
(CELLS/MM^2 EXCEPT FILAMENTOUS TAXA EXPRESSED AS NUMBER OF 50μ LENGTHS)

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
CYANOPHYTA												
Lyngbya spp.	411	31	145	1	5	105	236	127	0	0	0	0
CHRYSOPHYTA												
Bicoeca lacustris	0	0	0	482	144	823	1,220	196	947	1,796	616	1,105
Meridion circulare	36	25	11	1	1	7	27	452	328	1	21	1
Achnanthes lanceolata	127	460	63	16	8	32	221	598	119	54	28	62
A. minutissima	1,315	6,630	4,954	1,062	439	3,095	3,715	15,583	4,739	1,003	1,533	2,319
Navicula arvensis	46	27	85	11	12	10	92	406	132	14	53	13
N. cryptocephala	950	601	116	12	170	50	385	3,696	253	33	468	109
N. pelliculosa	22	5	24	10	109	35	50	675	7,291	272	11	14
Cymbella affinis	22	59	35	6	4	25	35	368	0	1	553	3
Gomphonema intricatum	58	387	275	58	16	74	227	3,665	1,540	78	105	41
Total (All Species)	3,505	8,856	5,918	1,790	2,156	4,407	6,930	26,974	15,908	3,389	4,292	3,978

[a] 10 most abundant taxa over the study period.

TABLE 2.38
MEAN ORGANIC WEIGHTS (G/50 CM^2) OF PERIPHYTON COMMUNITIES DURING RBOSP BASELINE STUDIES, OCTOBER 1974 THROUGH AUGUST 1976

	1974	1974-75	1975						1976			
	Oct-Nov.	Dec-Jan.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.-Aug.	Aug-Sep.
Spring Brook Habitats	0.0528	0.1356	0.0722	0.0406	0.0361	0.0383	0.0549	0.1176	0.0533	0.0230	0.0292	0.0669
Pond Habitats	0.3528	0.2274	0.9077	0.4071	0.3354	0.0679	0.0513	0.2991	0.1623	0.0908	0.0712	0.1406
Yellow Creek	0.1474	--	0.0920	0.2143	0.0368	0.0464	0.0530	0.0520	0.0373	0.2093	0.1776	0.1833
White River - Back Channel	0.3954	0.6124	0.4685	0.2725	0.1685	0.2850	0.3733	0.4371	0.1498	0.4370	0.3532	0.3623
White River - Open Channel	0.5197	0.5113	0.4152	0.1520	0.1471	0.3649	0.5163	0.5171	0.2521	0.3997	0.4220	0.4962
Yellow Creek - Artificial Substrates	--	--	--	--	0.0190	0.0192	0.0492	--	0.0295	--	0.0113	--
White River - Artificial Substrates	--	--	--	--	0.0204	0.0540	0.0271	--	0.0375	--	0.0173	0.0137

-- No data

TABLE 2.39
MEAN CHLOROPHYLL a (MG/M^2) OF PERIPHYTON COMMUNITIES DURING RBOSP BASELINE STUDIES, MAY 1975 THROUGH SEPTEMBER 1976.

	1975				1976			
	May-June	July-Aug	Aug-Sep.	Oct.	Apr.	June	July	Aug-Sep.
Spring Brook Habitats	0.4	0.6	1.5	2.9	5.2	1.1	0.8	1.7
Pond Habitats	3.9	4.6	4.0	7.1	3.7	1.0	1.7	1.7
Yellow Creek	1.3	0.4	1.3	1.5	2.8	3.6	2.1	3.4
White River - Back Channel	2.3	4.8	22.6	9.2	12.5	6.9	6.9	6.2
White River - Open Channel	2.7	4.4	23.9	9.8	14.6	9.2	9.7	8.3
Yellow Creek - Artificial Substrates	0.8	0.2	0.9	1.4	3.6	3.2	0.4	0.2
White River - Artificial Substrates	<0.1	1.6	16.1	1.8	10.3	2.5	2.3	2.5

TABLE 2.40
DIVERSITY INDICES OF PERIPHYTON COMMUNITIES OF THE SPRING BROOK STATIONS DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976

Date	Shannon Index	Evenness	Richness	Number of Species
Oct. 74	1.84	0.54	1.48	11.7
Dec. 74	1.54	0.44	1.59	13.7
Apr. 75	1.29	0.36	1.50	12.2
June 75	1.49	0.39	2.00	14.8
July 75	2.16	0.54	2.10	16.4
Aug. 75	1.77	0.44	2.24	16.0
Oct. 75	1.83	0.46	1.89	15.4
Nov. 75	1.69	0.45	1.50	13.6
Apr. 76	1.53	0.41	1.75	13.3
June 76	1.71	0.48	1.75	12.5
July 76	1.86	0.47	2.03	15.1
Aug. 76	1.63	0.42	1.75	14.4

(11.7-16.4) and Shannon indices (1.29-2.16) of the spring brook habitats were generally lower than in other habitat types on the site. Confidence limits for periphyton data appear in RBOSP Progress Report 10.

Predominant species of the spring brook habitats, in order of decreasing abundance, were Achnanthes minutissima, Navicula pelliculosa, Bioeca lacustris, Navicula cryptocephala, and Gomphonema intricatum. Achnanthes minutissima frequently dominated the spring brook habitats and developed maximum populations in the fall and early spring. The highest mean density for this species (15,583 cells/mm^2) was observed in the fall at the beginning of the second sampling year. Achnanthes minutissima is an indicator of high oxygen concentrations in alkaline water (Lowe 1974), such as is found in the spring brook habitats throughout the year.

Mean cell densities of Navicula pelliculosa were much higher during the second year of sampling than the first; maximum densities developed in the spring. This organism is a small, thinly silicified diatom that attains optimum development in waters with a pH around 8 and a high mineral content (Lowe 1974).

Navicula cryptocephala and Gomphonema intricatum developed seasonal population peaks during the late fall and attained highest densities during the second year of sampling. Both are cosmopolitan species which attain highest densities in alkaline waters (Lowe 1974).

Bicoeca lacustris was present in most of the months sampled and reached a peak density of 1,796 cells/mm^2 in June of the second year. It is a temporarily or permanently sessile flagellate which is enclosed in a delicate shell. This inconspicuous species is often overlooked, thus its ecology is insufficiently known. Other members of this chrysophyte family are known to live on organic substances released through bacterial decay (Grell 1973)

2. Ponds

Organic weight of periphyton peaked in April of the first year at 0.9077 g/50 cm^2; a lesser peak of 0.2991 g/50 cm^2 was observed in November of the second

year (Table 2.38). During the first year, chlorophyll a varied little from June through August. A slight peak of 4.6 mg/m^2 occurred in July (Table 2.39). During the second year, the highest chlorophyll a values (3.7 and 3.4 mg/m^2) were found in April and August.

Periphyton cell densities showed a seasonal maximum during the early winter of both 1975 and 1976 when mean cell densities (15,907 and 14,645 $cells/mm^2$, respectively) were approximately twice as high as at any other time (Table 2.41). Mean total cell densities were slightly higher during the first year of sampling.

Average number of species in periphyton collections from pond habitats ranged from 16 to 24, which was usually higher than the number of species in spring brook habitats.

Periphyton communities of the pond habitats were more diverse than those of the spring brook habitats. This greater diversity was reflected in the higher values of Shannon diversity index, evenness index, richness index, and average number of species. High Shannon diversity indices (2.66 to 2.75) occurred during April, June, and July of the first year; whereas the highest value (2.99) was observed in August of the second year (Table 2.42).

Predominant species of the pond habitats, in order of decreasing abundance, were Achnanthes minutissima, Nitzschia frustulum, Nitzschia denticula, Synedra amphicephala, and Navicula cryptocephala.

Over the study period, Achnanthes minutissima, an indicator of oxygenated water, developed mean densities five times greater than the next most abundant species. It was most abundant during the fall and early winter when densities were generally greater than 5,000 $cells/mm^2$.

Nitzschia frustulum displayed seasonal population patterns that were similar to those of Achnanthes minutissima. Nitzschia frustulum exhibited largest populations (1,150 - 1,300 $cells/mm^2$) during the early winter of the first year. This species grows best at a pH above 7 and is suspected of being an obligate nitrogen heterotroph (Lowe 1974).

TABLE 2.41

DOMINANT PERIPHYTON TAXA[a] AT POND HABITATS DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976 (CELLS/MM^2 EXCEPT FILAMENTOUS TAXA EXPRESSED AS NUMBER OF 50μ LENGTHS)

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
CHRYSOPHYTA												
Bicoeca lacustris	0	0	0	0	17	0	83	0	1,157	2,201	0	0
Synedra amphicephala	622	1,752	233	94	4	15	90	2,434	122	12	1	0
Achnanthes minutissima	1,704	5,450	2,936	3,588	3,970	4,270	6,222	5,242	1,097	2,257	1,477	334
Navicula cryptocephala	133	968	379	310	353	65	146	915	311	108	144	112
Cymbella affinis	22	568	71	190	495	1,382	33	45	6	19	0	4
Gomphonema intricatum	34	33	534	18	7	6	33	198	1,833	20	200	46
Nitzschia acicularis	13	16	11	2	80	0	3	1,861	5	1	2	27
Nitzschia denticula	19	592	563	2,647	709	658	34	148	9	52	18	4
Nitzschia frustulum	197	1,301	520	423	273	100	936	1,150	154	374	329	194
Surirella ovata	19	3,023	259	18	2	0	8	26	354	18	7	28
Total (All Species)	3,618	15,907	6,966	8,184	7,871	6,982	8,408	14,645	6,619	5,454	2,533	2,035

[a]10 most abundant taxa over the study period.

TABLE 2.42
DIVERSITY INDICES OF PERIPHYTON COMMUNITIES OF THE POND STATIONS DURING RBOSP BASELINE STUDIES, OCTOBER 1974 to AUGUST 1976.

Date	Shannon Index	Evenness	Richness	Number of Species
Oct. 74	2.36	0.60	2.00	16.2
Dec. 74	2.26	0.53	1.94	18.8
Apr. 75	2.73	0.63	2.32	21.1
June 75	2.66	0.59	2.64	22.7
July 75	2.75	0.60	2.78	23.8
Aug. 75	1.79	0.42	2.32	18.9
Oct. 75	1.83	0.42	2.63	22.8
Nov. 75	2.19	0.48	2.42	22.9
Apr. 76	2.35	0.52	2.62	23.3
June 76	1.54	0.39	1.91	16.3
July 76	1.96	0.47	2.18	18.8
Aug. 76	2.99	0.68	2.67	21.0

Nitzschia denticula showed high densities during 1975, with a peak of 2,647 cells/mm^2 in June. During the second year, this species was present only in low numbers, with a peak of only 148 cells/mm^2 in November. Nitzschia denticula is reported to be alkaliphilous and to grow best in highly oxygenated waters with a pH from 8.2 to 8.5 (Lowe 1974).

Synedra amphicephala displayed similar population trends during the two sampling years. A seasonal peak occurred during the winter of each year when 1,752 and 2,434 cells/mm^2 developed.

Navicula cryptocephala developed maximum densities during the early winter of each year. Population densities of this species declined throughout the spring and summer of both years.

Gomphonema intricatum was present in all samples and had definite population peaks in April (534 cells/mm^2 in 1975; 1,833 cells/mm^2 in 1976).

Bicoeca lacustris, Cymbella affinis, Nitzschia acicularis, and Surirella ovata were usually present in low densities in the pond periphyton communities, and each species developed only one pronounced population peak throughout the two-year study.

3. Yellow Creek

In Yellow Creek, the highest organic weights of 9.2143 and 9.2093 g/50 cm^2 were observed during June of each year (Table 2.38). Chlorophyll a was measured from June through August 1975 and was highest in June and August when values reached 1.3 mg/m^2 (Table 2.39). Chlorophyll a concentrations displayed two slight peaks of 3.6 and 3.4 mg/m^2 in July and August of the second year.

Total mean periphyton densities in creek habitats were greatest (12,547 to 14,511 cells/mm^2) during October of both years (Table 2.43). After the fall peak of each year, the periphyton standing crops gradually decreased throughout the spring and summer.

TABLE 2.43

DOMINANT PERIPHYTON TAXA[a] AT YELLOW CREEK HABITATS DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976. (CELLS/MM^2 EXCEPT FILAMENTOUS TAXA EXPRESSED AS NUMBER OF 50μ LENGTHS)

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
CYANOPHYTA												
Calothrix spp.	869		0	384	17	7	0	75	0	9	194	27
CHRYSOPHYTA												
Cyclotella menghiniana	370	FROZEN	14	108	26	10	31	3	0	247	118	114
Synedra amphicephala	15		8	0	0	0	5	21	1,069	7	0	0
Achnanthes minutissima	5,614		1,506	3,559	127	912	11,605	6,177	44	382	30	123
Navicula cryptocephala	104		28	68	99	36	86	10	46	55	116	222
N. pelliculosa	0		2,553	56	544	2	8	3	1,019	426	24	30
Cymbella affinis	7,050		102	21	8	1	0	8	0	0	1	11
Nitzschia frustulum	71		51	378	66	258	282	88	20	1,788	1,281	6,515
N. holsetica	0		0	0	54	44	0	75	198	3	46	270
Surirella ovata	0		264	6	1	3	2	9	1,332	94	4	14
Total (all species)	14,511		4,796	5,116	1,719	1,699	12,547	6,774	4,334	3,468	2,060	7,993

[a]10 most abundant taxa over the study period.

The number of species was lowest in October of both 1975 and 1976, resulting in the lowest value for the Shannon diversity index for each year (Table 2.44). As periphyton communities developed through the spring and summer months, a slight increase in number of species and diversity occurred in Yellow Creek during both years.

The dominant species in the Yellow Creek periphyton samples were Achnanthes minutissima, Nitzschia frustulum, Cymbella affinis, Navicula pelliculosa, and Surirella ovata.

Achnanthes minutissima developed maximum cell densities in June of the first year and in the fall and winter of both years. The population peak of this species in October of the second year (11,605 cells/mm^2) was about twice as high as the first year's fall maximum (5,614 cells/mm^2).

Nitzschia frustulum maintained relatively stable populations, with densities below 400 cells/mm^2 during the first year collections. In the second year of sampling, a definite population pulse began in June and the organism attained densities of 6,515 cells/mm in the final collections of August 1976.

Highest populations (7,050 cells/mm^2) of Cymbella affinis were observed in October 1974; after this initial peak, populations remained at levels below 100 cells/mm^2. This species is considered alkaliphilous to alkalibiontic, with best development in waters with pH from 7.8 to 8.5 (Lowe 1974).

Navicula pelliculosa showed a definite pulse of 2,553 cells/mm^2 in April of the first year and a lesser pulse of 1,069 cells/mm^2 in April of 1976.

Surirella ovata showed a definite population maximum in the early spring of both years. The peak in April of the first year was represented by 264 cells/mm^2, whereas the spring peak of the second year was more pronounced at 1,332 cells/mm^2. Surirella ovata is reported to be an alkaliphilous species that attains optimum development during the winter in running waters with a pH of 7.5 to 8 (Lowe 1974).

TABLE 2.44
DIVERSITY INDICES OF PERIPHYTON COMMUNITIES OF THE YELLOW CREEK STATION DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976

Date	Shannon Index	Evenness	Richness	Number of Species
Oct. 74	1.46	0.50	0.89	9.6
Dec. 74	Frozen	Frozen	Frozen	Frozen
Apr. 75	1.53	0.42	1.40	12.7
June 75	1.57	0.43	1.41	13.0
July 75	2.77	0.65	2.46	19.3
Aug. 75	1.77	0.46	1.80	14.0
Oct. 75	0.76	0.20	1.28	12.7
Nov. 75	1.60	0.41	1.98	14.0
Apr. 76	2.34	0.60	1.73	15.4
June 76	2.25	0.57	2.00	16.2
July 76	2.24	0.52	2.40	19.0
Aug. 76	2.28	0.55	2.14	17.7

4. White River

Organic weights of periphyton of the back channel and open channel areas of the White River were similar. Highest organic weights (0.5113 to 0.5197 g/50 cm^2) occurred during the fall and early winter of each collection year (Table 2.38). During the first summer, the highest chlorophyll a value (23.9 mg/m^2) occurred in August, whereas during the second year, the highest chlorophyll a value (14.6 mg/m^2) occurred in April (Table 2.39).

Species composition and total cell densities of both river habitats were very similar throughout the two-year period (Tables 2.45 and 2.46).

Highest cell densities occurred during the late summer and fall of both sampling years. Periphyton cell densities were high (11,962 to 17,642 cells/mm^2) when sampling began in the fall and early winter of 1974. Standing crops increased in August from 21,093 to 30,098 cells/mm^2 and high cell densities were maintained through November. Densities decreased in April to mean levels of 6,000 to 11,000 cells/mm^2 and populations remained at these moderate densities through the rest of the study period. The mean number of species in the periphyton communities of the White River ranged from 14.9 to 28.2 and did not display seasonal trends.

Diversity indices were generally higher in the White River than in any of the Yellow Creek basin habitats. Highest diversity indices in the river habitats occurred during the summer of the first year and in June of the second year (Tables 2.47 and 2.48). Diversity was more affected by evenness of species abundance than by number of species. The number of species, as well as evenness, tended to be higher than in the other habitats. Mean diversity indicies did not show seasonal trends but fluctuated moderately throughout the study period.

Predominant taxa of the White River periphyton communities were Epithemia sorex, Nitzschia dissipata, Navicula cryptocephala, Navicula viridula, Amphora ovalis var. pediculus, and Calothrix spp.

TABLE 2.45

DOMINANT PERIPHYTON TAXA[1] AT BACK CHANNEL WHITE RIVER HABITATS DURING RBOSP BASELINE STUDIES
OCTOBER 1974-AUGUST 1976
(CELLS/mm^2 EXCEPT FILAMENTOUS TAXA EXPRESSED AS NUMBER OF 50μ LENGTHS)

	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
CYANOPHYTA												
Lyngbya spp.	655	1,039	171	140	2,289	1,196	1,809	671	1	315	0	7
Calothrix spp.	740	457	432	208	18	72	197	666	219	1,890	1,557	2,398
CHRYSOPHYTA												
Diatoma vulgare	439	1,058	79	3	80	207	73	5,005	8	96	0	2
Navicula cryptocephala	567	758	1,819	332	500	850	1,037	2,339	780	1,717	278	329
Navicula viridula	11	36	2,488	40	125	82	68	2,090	4,880	547	5	18
Amphora ovalis var. pediculus	7	216	243	1,138	996	939	878	1,355	559	1,414	1,296	279
Gomphonema olivaceum	299	229	799	6	304	139	332	725	1,090	788	15	18
Epithemia sorex	5,123	4,708	812	210	44	12,221	10,315	5,204	785	150	1,804	2,550
Nitzschia dissipata	313	947	1,622	90	307	1,443	1,671	6,419	801	1,136	51	84
Nitzschia frustulum	495	443	166	254	118	1,060	619	1,496	298	1,099	106	132
Total (All Species)	11,962	13,655	11,672	3,682	6,311	21,093	19,329	31,288	10,944	11,688	6,116	7,765

[a] 10 most abundant taxa over the study period.

TABLE 2.46
DOMINANT PERIPHYTON TAXA[a] AT OPEN CHANNEL WHITE RIVER HABITATS DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976
(CELLS/MM^2 EXCEPT FILAMENTOUS TAXA EXPRESSED AS NUMBER OF 50μ LENGTHS)

	1974		1975						1976			
	Oct.	Dec.	Apr	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
CYANOPHYTA												
Lyngbya spp.	314	2,550	264	100	2,289	645	1,298	222	6	1,060	0	11
Calothrix spp.	3,247	692	393	150	18	115	143	632	238	458	1,447	2,155
CHRYSOPHYTA												
Diatoma vulgare	208	2,530	37	0	80	268	187	3,991	23	160	2	4
Navicula cryptocephala	548	966	1,577	131	723	972	1,885	2,165	1,274	1,790	390	433
Navicula Salinarum var. *intermedia*	1,004	614	66	1	91	1,297	859	878	52	8	19	232
Navicula viridula	8	89	1,883	18	132	104	71	1,826	3,325	581	15	17
Amphora ovalis var. *pediculus*	27	115	362	823	1,096	1,239	1,636	1,182	717	1,775	1,403	1,090
Epithemia sorex	7,609	4,592	1,653	62	144	19,389	13,173	6,393	1,665	263	1,519	2,425
Nitzschia dissipata	541	1,234	1,157	60	360	2,164	2,756	5,886	1,339	1,085	138	244
Nitzschia frustulum	467	634	133	503	176	1,052	810	1,479	156	867	136	234
Total (All Species)	16,154	17,642	9,600	2,437	7,762	30,098	25,602	29,727	10,820	11,966	6,318	8,929

[a]10 most abundant taxa over the study period.

TABLE 2.47
DIVERSITY INDICES OF PERIPHYTON COMMUNITIES OF THE BACK CHANNEL OF THE WHITE RIVER STATIONS DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976.

Date	Shannon Index	Evenness	Richness	Number of Species
Oct. 74	2.69	0.62	2.10	20.6
Dec. 74	2.93	0.66	2.27	22.2
Apr. 75	3.22	0.70	2.50	24.4
June 75	3.04	0.71	2.26	19.4
July 75	3.34	0.72	2.80	24.9
Aug. 75	2.51	0.53	2.67	26.9
Oct. 75	2.57	0.55	2.47	24.8
Nov. 75	3.48	0.72	2.65	28.2
Apr. 76	2.44	0.58	1.95	19.0
June 75	3.38	0.75	2.34	22.8
July 76	2.52	0.65	1.85	14.9
Aug. 76	2.79	0.62	2.46	22.7

TABLE 2.48
DIVERSITY INDICES OF PERIPHYTON COMMUNITIES OF THE OPEN CHANNEL OF THE WHITE RIVER STATIONS DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976.

Date	Shannon Index	Evenness	Richness	Number of Species
Oct. 74	2.44	0.56	2.02	20.4
Dec. 74	3.09	0.68	2.38	24.0
Apr. 75	3.09	0.70	2.22	21.2
June 75	2.31	0.57	2.11	16.9
July 75	3.41	0.74	2.71	24.8
Aug. 75	2.11	0.44	2.52	26.4
Oct. 75	2.70	0.58	2.47	25.0
Nov. 75	3.34	0.70	2.57	27.4
Apr. 76	2.82	0.66	2.09	20.2
June 76	3.61	0.78	2.60	25.3
July 76	2.57	0.66	1.63	15.1
Aug. 76	2.95	0.66	2.42	22.7

Epithemia sorex developed population peaks in the fall months, but the maximum pulse of 12,221 to 19,389 cells/mm^2 developed in the back and main channels during August 1975. This species is considered alkaliphilous and grows best in water with pH of 8.3 to 8.5 (Lowe 1974).

Highest numbers of Nitzschia dissipata occurred in the fall and winter of each year. This species is considered alkaliphilous to alkalibiontic and develops highest densities in highly oxygenated water with a pH about 8.0 (Lowe 1974).

Navicula cryptocephala developed a small peak of 1,577 to 1,819 cells/mm^2 in April of the first year, although the highest densities of 2,165 to 2,339 cells/mm^2 occurred during the autumn of the second year.

Amphora ovalis var. pediculus developed high numbers during the late summer of the first year and the early summer of the second year. This species did not display seasonal patterns of abundance and was present in all months.

Calothrix spp., a filamentous blue-green alga, developed high densities in the fall and late summer of 1976. Lyngbya spp., another blue-green filamentous alga, became very abundant in July 1976.

C. Distribution and Abundance on Artificial Substrates

1. Yellow Creek

Organic weight of periphyton on artificial substrates in Yellow Creek showed little variation (0.0190 to 0.0197 g/50 cm^2) during 1976; while during the following year, biomass peaked in October at 0.0492 g/50 cm^2 (Table 2.38). (0.8 to 0.9 mg/m^2) in June and August (Table 2.39). During April of the second year, chlorophyll a peaked at 3.6 mg/m^2. Total mean cell densities on the artificial substrates in Yellow Creek were highest (3,286 cells/mm^2) in June of the first year, whereas in the second year, densities were highest (6,255 cells/mm^2) in October (Table 2.49).

TABLE 2.49
DOMINANT PERIPHYTON TAXA[a] OF ARTIFICIAL SUBSTRATES IN YELLOW CREEK HABITATS DURING RBOSP BASELINE STUDIES, JUNE 1975 TO AUGUST 1976. (CELLS/MM^2)

	1975				1976		
	June	July	Aug.	Oct.	Apr.	June	July
Cyclotella meneghiniana	86	18	29	37	-	164	11
Fragilaria vaucheriae	-	-	3	-	90	202	-
Synedra amphicephala	3	-	-	-	556	112	-
Achnanthes minutissima	2,794	122	227	3,440	16	594	2
Navicula cryptocephala	14	17	4	2,093	43	115	3
Nitzschia capitellata	-	8	41	-	228	-	-
Nitzschia frustulum	20	10	108	120	22	670	85
Nitzschia holsetica	-	18	119	-	152	18	9
Nitzschia palea	42	39	8	126	9	-	-
Surirella ovata	27	-	-	-	1,017	35	1
Total (all species)	3,286	318	1,102	6,255	2,539	2,292	186

[a]10 most abundant taxa over the study period.

The dominant species were Achnanthes minutissima, Navicula cryptocephala, Surirella ovata, Nitzschia frustulum, and Synedra amphicephala.

Achnanthese minutissima populations reached a high of 2,799 cells/mm^2 during June of 1975 and a high of 3,440 cells/mm^2 in October 1976.

Densities of Navicula cryptocephala remained below 20 cells/mm^2 during the first year; populations peaked at 2,093 cells/mm^2 in October of the following year. Surirella ovata was present in low densities (27 cells/mm^2) in June of the first year and in April of the second year, populations peaked at 1,017 cells/mm^2. Nitzschia frustulum peaked at 108 cells/mm^2 during August of 1975 and at 670 cells/mm^2 during June of 1976. Synedra amphicephala had densities less than 5 cells/mm^2 observed in April of the second year.

2. White River

The highest organic weight during 1976 was 0.0540 g/50 cm^2, which occurred in August, whereas during the following year, the highest organic weight observed was 0.0375 g/50 cm^2 in April (Table 2.38). Chlorophyll a was low during the first year; the highest value of 0.0161 mg/cm^2 was observed in August (Table 2.39). Chlorophyll a was highest in June, July, and August of the second year when values of 2.3 to 2.5 mg/m^2 were observed.

Total mean cell densities of the White River artificial substrates reached a maximum of 9,641 cells/mm^2 in August of the first year and a maximum of 3,453 cells/mm^2 during April of the second year (Table 2.50). Dominant species that colonized the artificial substrates in the White River were, in order of decreasing abundance, Epithemia sorex, Nitzschia dissipata, Navicula viridula, Gomphonema olivaceum, and Cocconeis placentula.

Epithemia sorex developed very high densities (6,654 cells/mm^2) during August of 1975. This population pulse coincided with high densities of Ephithemia sorex which occurred on the natural substrates of the White River. During the second collection year, the highest densities of Ephithemia sorex (170 cells/mm^2) occurred in August. Nitzschia dissipata developed high densities

TABLE 2.50
DOMINANT PERIPHYTON TAXA[a] OF ARTIFICIAL SUBSTRATES IN WHITE RIVER HABITATS DURING RBOSP BASELINE STUDIES, JUNE 1975 TO AUGUST 1976. (CELLS/MM^2)

	1975				1976			
	June	July	Aug.	Oct.	Apr.	June	July	Aug.
Cocconeis pediculus	-	5	10	11	8	482	13	15
Cocconeis placentula	3	8	25	58	8	466	79	215
Navicula cryptocephala	4	97	171	138	220	177	7	7
Navicula salinarum var. intermedia	46	272	211	20	-	2	5	-
Navicula tripunctata	-	37	74	54	361	117	4	2
Navicula viridula	-	46	23	12	1,763	89	-	2
Gomphonema olivaceum	30	406	102	201	321	95	11	2
Epithemia sorex	-	4	6,654	581	8	3	154	170
Nitzschia frustulum	5	-	472	153	20	21	42	9
Nitzschia dissipata	1	139	1,241	718	207	102	2	3
Total (All species)	180	1,646	9,641	2,707	3,453	2,295	496	668

[a]10 most abundant taxa over the study period.

(1.214 cells/mm^2) in August of the first year. These species developed populations of 207 cells/mm^2 during May of the second year. Populations of Navicula viridula were less than 50 cells/mm^2 during the first year; and during April of the second year, the populations peaked at 1,763 cells/mm^2. Gomphonema olivaceum developed maximum densities of 406 cells/mm^2 during July of the first year and 321 cells/mm^2 during April of the second year. Cocconeis placentula maintained populations below 60 cells/mm^2 during the first year, but during June of the second year, populations peaked at 466 cells/mm^2.

Diversity indices for periphyton on artificial substrates (Table 2.51) were similar to those for river habitats (Table 2.47 and 2.48). The average number of species varied little.

TABLE 2.51
DIVERSITY INDICES OF PERIPHYTON COMMUNITIES ON ARTIFICIAL SUBSTRATES DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976.

Date	Shannon Index	Evenness	Richness	Number of Species
June 75	1.12	0.31	1.61	12.8
July 75	3.15	0.72	3.18	22.0
Aug. 75	2.32	0.52	2.88	22.8
Oct. 75	2.43	0.54	2.74	22.4
Apr. 76	2.56	0.58	2.62	21.8
June 76	2.97	0.68	2.55	20.8
July 76	2.68	0.66	3.11	16.8
Aug. 76	2.38	0.61	2.35	15.0

V. BENTHOS

A. Species Composition

The White River and the Yellow Creek drainage (Figure 2.2) offers a large number of microhabitats for aquatic invertebrates to colonize and large numbers of taxa are found in these waters. Representatives of six phyla, 71 familes and 168 genera were collected in the study area during the two years of macroinvertebrate sampling. A comprehensive taxonomic list of all taxa is presented in RBOSP Progress Report 10. Most taxa identified from the study area are in the classes Insecta (Arthropoda) and Oligochaeta (Annelida). Confidence limits for benthos data appear in RBOSP Progress Report 10.

B. Distribution and Abundance

1. Spring Brooks

One hundred and fifty-five taxa were collected from the spring brook habitats. Thirty-six families and 88 genera have been identified thus far. Densities of more abundant taxa (number of organisms/m^2) collected over the survey period are listed in Table 2.52. Distributions of macroinvertebrates by habitat appear in RBOSP Progress Report 10.

Segmented worms (Annelida), flatworms (Platyhelminthes), and roundworms (Nematoda), were the most common non-arthropods in benthos samples. Insecta were the dominant Arthropoda. Larval stages of dipterans were particularly abundant. Chironomidae, Simuliidae (Simulium), Ceratopogonidea, Tipulidae (mainly Holorusia) and Anthomyiidae (Limnophora aequifrons) were numerous. Ephemeropterans of the genus Baetis were one of the more abundant taxa in the spring brooks. The large numbers of Chironomidae were mainly Orthocladiinae and Chironominae. Within the Orthocladiinae, Eukiefferiella, Orthocladius, Parametriocnemus, Paraphaenocladius, Orthocladius (Euorthocladius), and Thienemanniella were the most common genera. Genera of Chironominae included Micropsectra, Phaenopsectra, Paratendipes, and Polypedilum (fallax).

TABLE 2.52
MOST ABUNDANT MACROINVERTEBRATE TAXA[a] OF SPRING BROOK HABITATS DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976. (ORGANISMS $1m^2$

Taxon	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
Tricladida	68	0	0	0	0	0	149	81	1	145	334	57
Nematoda	66	159	102	75	18	14	10	17	8	6	15	18
Enchytraeidae	45	18	176	194	23	11	28	36	12	12	48	120
Naididae	787	1,495	3,784	184	18	76	98	523	1	49	65	159
Baetis	4	582	1,055	230	131	275	107	51	105	26	38	20
Holorusia	188	96	69	64	30	50	67	155	55	34	30	45
Ceratopogonidae	96	33	207	120	7	22	89	67	10	36	48	8
Chironomidae	1,583	6,089	4,996	924	1,639	4,153	1,747	3,153	1,174	3,622	4,170	2,278
Simuliidae	1,367	4,393	739	1	347	440	226	98	31	18	394	544
Limnophora aequifrons	172	190	15	1	36	59	51	56	1	25	35	85
Total (all species)	8,277	22,513	11,967	2,012	2,694	6,032	6,027	7,431	1,954	5,292	6,821	5,064

[a] 10 most abundant taxa over the study period

Oligochaeta found in the spring brooks were primarily members of the family Naididae; Enchytraeidae, Haplotaxidae, and Tubificidae were found at some stations.

No major changes in the composition of the fauna occurred during the two years of collecting, although a shirt in insect emergence periods was observed. Field observers believe that this difference can be attributed to weather conditions. Emergence occurred later and its duration was shorter in the spring of 1975 than in spring of 1976. Warming conditions occurred later than in 1976.

Densities of all taxa collected are reported in RBOSP Progress Reports 2 to 9. Species diversity indices for the spring brook habitat types are presented in Table 2.53. The Shannon-Weiner, species richness, and evenness indices and mean number of species are compared by date. Within the spring brook habitat, continuously flowing stations generally supported a more diverse faunal community than ephemeral stations.

Variations between the basic habitat types in the study area are considerable. For example, spring brooks of the headwater Stations 1-4 are extremely small in size, varying from two to 48 inches (in vernal runoff periods) in width and from one to three inches in depth, with maximum water velocities of no more than 2.5 feet/second. Substrates in the spring brooks are dominated by coarse sand and gravel fractions. During low flow periods, the finer fractions (silt, clay, and detritus) accumulate. There is very little macrophytic growth in the spring brooks, but periphyton covers the gravel and other substrates. Other spring brook stations (6, 10-12, 15-18) are more ephemeral in nature. This type of habitat favors those species which can easily invade a given location by various means (drifting, active upstream movement) or which can burrow into the hyporheic zone during periods of drought. Substrates at these ephemeral stations are similar to the headwater rheocrenes (spring brooks).

2. Ponds

The ten most abundant taxa of the pond habitats are listed in Table 2.54. The pond community was represented by 160 benthic taxa, included 38

TABLE 2.53

SUMMARY OF DIVERSITY INDICES FOR BENTHIC MACROINVERTEBRATES COLLECTED AT THE SPRING BROOKS DURING RBOSP AQUATIC BASELINE STUDIES, BETWEEN OCTOBER-NOVEMBER 1974 AND AUGUST-SEPTEMBER 1976

Station	Shannon Index	Richness	Evenness	Number of Species
		October - 1974		
1	2.97	2.09	.71	19
2	2.94	2.11	.71	18
3	2.71	1.60	.71	13
4	2.91	2.42	.65	23
5[b]				
7	3.07	1.75	.78	15
8	1.98	1.97	.45	20
9	2.51	1.98	.61	17
10[b]				
11[b]				
12[b]				
13	2.79	2.35	.60	24
14[b]				
15[b]				
16[b]				
17[b]				
18[b]				
		December - 1974		
1[a]				
2[a]				
3	2.95	1.85	.74	16
4	2.08	2.34	.44	25
5[a]				
7[a]				
8	1.55	1.90	.36	20
9	2.96	1.91	.72	17
10[a]				
11[a]				
12[a]				
13	3.05	2.47	.63	28
15[a]				
16[a]				
17[a]				
18[a]				
		April - 1975		
1	1.48	1.01	.46	9
2	1.98	1.94	.49	17
3	2.92	2.42	.66	21
4	2.93	2.29	.64	23
5[b]				
7	2.86	1.40	.86	10
8	2.21	1.88	.53	17
9	2.60	1.68	.63	18
10[b]				
11[b]				
12[b]				
13	2.72	2.03	.61	22
14[b]				
16[b]				
17[b]				
18[b]				
		June - 1975		
1	2.46	1.50	.57	13
2	2.48	1.12	.90	7
3	3.41	2.16	.81	19
4	2.29	.89	.95	5
6	1.91	.70	.98	4
7	3.46	2.40	.82	19
8	1.19	.35	1.00	2
9	3.43	2.43	.76	23
10[b]				
11[b]				
12[b]				
13	1.97	.81	.93	5
14[b]				
15[b]				
16[b]				
18[b]				
		July - 1975		
1	2.90	2.06	.71	17
2	2.93	1.91	.72	17
3	1.85	1.65	.47	15
4	2.99	2.04	.70	19
5[b]				
7	3.10	1.88	.78	16
8	2.44	1.24	.76	9
9	3.08	2.53	.69	22
10[b]				
11[b]				
12[b]				
13	2.51	1.10	.90	7
15	1.57	1.74	.41	14
16[b]				
17	1.68	.57	.97	4
18	1.38	.50	1.00	3

TABLE 2.53 (Continued)

Station	Shannon Index	Richness	Evenness	Number of Species
		August - 1975		
1	1.79	1.49	.47	14
2	2.96	2.07	.72	18
3	2.77	2.42	.63	21
4	2.84	1.49	.78	12
6[b]				
7	3.13	2.08	.79	15
8	3.20	2.08	.74	20
9	2.13	1.86	.54	16
10[b]				
11[b]				
12	1.80	.64	.91	4
13	3.37	2.40	.76	21
15[b]				
16[b]				
17	2.57	2.12	.57	22
18[b]				
		October - 1975		
1	1.81	1.99	.42	22
2	2.93	2.37	.67	21
3	3.02	2.25	.69	20
4	2.27	1.59	.61	13
6[b]				
7	1.90	1.61	.50	14
8	1.60	2.39	.35	23
9	2.37	1.85	.59	16
10[b]				
11[b]				
12	2.36	.97	.90	6
13	2.34	1.88	.59	16
15[b]				
16[b]				
17	2.19	1.55	.56	15
18[b]				
		November - 1975		
1	3.54	3.14	.72	31
2	3.40	2.43	.76	23
3	3.39	2.21	.81	19
4	2.79	2.33	.64	21
6[b]				
7	2.54	1.61	.69	13
8	2.73	2.67	.57	27
9	2.75	1.75	.72	14
10[b]				
11[b]				
12[b]				
13	3.54	2.54	.78	24
15	2.21	1.46	.60	13
16[b]				
17	2.29	1.52	.60	14
18	1.72	1.13	.49	12
		April - 1976		
1[b]				
2	2.32	1.14	.76	8
3	1.84	.99	.60	9
4	1.77	1.72	.45	16
6[b]				
7	2.77	1.31	.89	9
8	2.04	.88	.77	6
9	2.47	1.11	.87	7
10[b]				
11[b]				
12[b]				
13	2.36	2.03	.58	17
15	1.84	1.52	.49	14
16[b]				
17	.32	.29	.15	3
18	2.36	1.14	.83	8

TABLE 2.53 (Continued)

Station	Shannon Index	Richness	Evenness	Number of Species
		June - 1976		
1	1.98	1.80	.50	17
2	.81	1.23	.24	11
3	2.53	1.92	.62	17
4	1.65	1.49	.45	13
6	2.30	.99	.89	6
7	3.50	2.24	.87	17
8	.95	.31	.63	2
9	3.53	2.74	.78	24
10[b]				
11[b]				
12[b]				
13	1.60	.72	.57	5
15	2.66	2.04	.61	21
16[b]				
17	2.34	1.39	.62	14
18	2.72	2.19	.62	21
		July - 1976		
1	1.60	.96	.50	9
2	2.04	1.37	.38	12
3	1.98	1.71	.48	18
4	3.11	2.47	.67	23
6[b]				
7	3.41	2.10	.83	17
8	1.64	1.85	.41	17
9	3.43	2.91	.72	27
10[b]				
11[b]				
12[b]				
13	3.65	2.96	.78	25
15[b]				
16[b]				
17[b]				
18[b]				
		August - 1976		
1	3.40	2.30	.80	19
2	3.05	2.16	.73	18
3	2.43	1.70	.60	16
4	2.78	2.02	.68	17
6[b]				
7	2.78	1.60	.75	13
8	3.26	2.32	.74	22
9	2.76	2.14	.66	18
10[b]				
11[b]				
12				
13	3.10	2.75	.66	26
15[b]				
16[b]				
17[b]				
18[b]				

[a] Stations were frozen at time of sampling

[b] Stations were dry at time of sampling

TABLE 2.54
MOST ABUNDANT MACROINVERTEBRATE TAXA[a] OF POND HABITATS DURING RBOSP
BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976. (ORGANISMS PER SQUARE METER)

	1974		1975						1976			
Taxon	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
Nematoda	47	611	2,843	1,025	3.274	274	10	119	290	233	605	4,412
Tubificidae	1,423	1,895	19,259	3,567	10,667	2,085	1,155	1,222	251	1,094	1,382	1,434
Naididae	16	362	1,026	5	15	46	106	423	22	10	328	2
Acari	0	20	332	326	226	366	336	1,018	88	32	95	34
Hyalella azteca	145	118	231	107	446	481	1,375	378	117	267	1,571	353
Callibaetis	829	0	567	342	34	180	39	194	0	0	2	20
Hydroptila	144	24	198	173	82	6	101	74	30	660	267	29
Ceratopogonidae	247	1,217	4,483	2,019	1,917	932	786	1,399	298	1,233	993	876
Chironomidae	1,948	34,463	34,470	3,168	4,456	10,736	1,977	25,474	8,427	2,942	4,073	1,980
Simuliidae	2,388	7,238	19,810	4,185	8,017	5,088	3,828	24,795	3,477	1,120	5,641	1,869
Total (all species)	7,601	46,365	85,874	16,004	29,720	21,477	10,821	56,694	13,189	7,849	16,281	13,319

[a]10 most abundant taxa over the study period

families and 90 genera. Major components of the pond fauna were dipterans (Chironomidae, Simuliidae, and, on certain dates, Ceratopogonidae). The Chironomidae were primarily represented by Orthocladiinae and Chironominae at the ponds, as they were in the spring brook habitats. Genera of Orthocladiinae included Orthocladiusm Paraphaenocladius, Parametriocnemus, Eukiefferiella, Theinemanniella, and Acricotopus. Chironomidae at Station 15 and 18, the seepage areas, were mainly Micropsectra, Microtendipes, and Tanytarsus. Aquatic Oligochaeta (in particular Tubificidae) were also abundant. Callibaetis, a mayfly, was abundant at Station 14 until the habitat disturbance previously described occurred. Certain organisms which were consistently found at the pond stations but seldom elsewhere included: Gastropoda, Helobdella stagnalis, Hyalella azteca, Callibaetis, Caenis, Corixidae, and Limnephilus.

Diversity indices for the pond stations are listed by date in Table 2.55. The total number of individuals at the pond stations was extremely high throughout the study period (see RBOSP Progress Report 2-9 for taxonomic diversity counts). The Shannon and species richness indices and number of taxa were quite high at Stations 5 and 19. The mean Shannon index at Station 5 was higher than at any other station. However, evenness among the species was not as close to unity at this station as at the White River stations.

Habitats which have been defined as ponds provide unique environments on Tract C-a. Two of these stations (5 and 19) are located downstream from weed-choked seepage areas. Substrates are compacted gravel with periphyton bound in small incrustations. Extremely high densities of certain taxa have been collected in these pond habitats and, as in the spring brooks, there are some taxa which are unique to this habitat type.

3. Yellow Creek

The most abundant benthic macroinvertebrates collected throughout the study period at the Yellow Creek stations are listed in Table 2.56. In total, 28 families and 51 genera were identified from this habitat. Aquatic dipterans

TABLE 2.55

SUMMARY OF DIVERSITY INDICES FOR BENTHIC MACROINVERTEBRATES (POND STATION), OCTOBER - NOVEMBER 1975 AND AUGUST - SEPTEMBER 1976

Station	Shannon Index	Richness	Evenness	Number of Species
		October - 1974		
5	2.21	2.00	.51	19
14	2.33	1.54	.61	15
19	2.66	2.11	.63	19
		December - 1974		
5	2.76	2.32	.64	20
14[a]				
19	2.21	1.87	.50	22
		April - 1975		
5	3.31	2.82	.66	33
14	2.04	1.29	.52	15
19	2.51	2.49	.52	29
		June - 1975		
5	3.81	3.08	.66	31
14	2.62	1.33	.73	12
19	2.11	2.02	.63	21
		July - 1975		
5	3.11	3.31	.60	38
14	1.54	1.45	.41	14
19	3.35	2.65	.76	22
		August - 1975		
5	1.98	2.47	.42	26
14	2.18	1.65	.52	18
19	3.27	2.14	.75	21
		October - 1975		
5	2.98	2.63	.63	27
14	3.14	1.88	.79	16
19	3.45	2.73	.76	26
		November - 1975		
5	3.52	2.96	.74	28
14	2.20	1.97	.49	21
19	2.13	2.28	.45	28
		April - 1976		
5	3.60	2.79	.79	24
14	1.81	1.64	.45	17
19	2.22	2.29	.49	23
		June - 1976		
5	3.58	3.23	.73	31
14	2.42	1.88	.59	18
19	2.75	2.03	.65	19
		July - 1976		
5	3.62	3.00	.74	30
14	3.44	2.82	.75	24
19	2.29	2.61	.49	27
		August - 1976		
5	2.88	2.64	.62	27
14	2.39	1.20	.73	6
19	3.27	2.23	.73	22

[a]Stations were frozen at time of sampling

TABLE 2.56
MOST ABUNDANT MACROINVERTEBRATE TAXA OF YELLOW CREEK HABITATS, DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976. (ORGANISMS $1M^2$)

Taxon	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
Nematoda	2		107	28	56	46	282	0	267	153	97	60
Tubificidae	1,712		913	119	432	30	664	52	903	309	450	1,496
Naididae	21,451		6	97	22	0	4	4	0	63	919	30
Acari	11		101	394	48	4	16	0	0	4	40	20
Collembola	15		0	34	0	6	0	0	2	0	0	8
Hydroporus	2		0	2	18	72	4	2	20	50	221	0
Ceratopogonidae	153		939	167	163	95	527	64	145	110	197	448
Chironomidae	1,090		5,578	760	145	338	453	861	724	2,747	1,353	662
Simuliidae	131		1,090	732	267	30	352	227	16	968	599	1,335
Limnophora aequifrons	37		4	0	0	0	2	0	0	32	0	0
Total (All Species)	24,734		8,859	2,379	1,193	664	2,739	1,229	2,088	4,522	3,958	4,148

[a] 10 most abundant taxa over the study period

were dominant; Chironomidae, Simuliidae, and Ceratopogonidae were the major families. Orthocladiinae comprised the Chironomidae almost exclusively. The major genera included Orthocladius, Eukiefferiella, Paraphaenocladius, and Acricotopus. Oligochaeta represented almost totally by Tubificidae, was the other large component of the creek habitat.

The average number of taxa (13) at the Yellow Creek stations was lower than elsewhere in the study area with exception of the ephemeral stations. Shannon index values for those locations were lower than the corresponding White River values (Table 2.57). This is not surprising since approximately 60 percent of the faunal assemblage of the Yellow Creek stations is composed of three dipteran families (Chironomidae, Simuliidae, and Ceratopogonidae).

Substrates at the Yellow Creek stations (20, 21, 22) were mainly sand and gravel. Silt and detritus composed a considerable proportion of substrate during some seasons. The relatively soluble alkaline substrates in the Yellow Creek drainage produced waters which were very alkaline. Specific conductivity and alkalinity reached their highest values in the lower stations of Yellow Creek. The high concentrations of total dissolved solids may be near the environmental limit of the biota at these stations.

4. White River

Additional literature regarding macroinvertebrates of the study area has recently been published by Colorado State University (CSU) (Ames & Frank 1976), which surveyed the fishes and aquatic macroinvertebrates of the White River and Yampa River. Data on the major insect taxa described in the report compared favorably with findings of the RBOSP study. Unfortunately, the detailed taxonomy of Chironomidae and the aquatic worms (Oligochaeta) were not covered in the CSU report and comparisons of these numerous organisms could not be made.

a. Back Channel. Thirty-nine families and 81 genera were described from this habitat during RBOSP baseline studies. The benthic community of the back channel habitat consisted primarily of Ephemeroptera, Trichoptera (Hydropsyche),

TABLE 2.57

SUMMARY OF DIVERSITY INDICES FOR BENTHIC MACROINVERTEBRATES (YELLOW CREEK STATION) OCTOBER - NOVEMBER 1974 AND AUGUST - SEPTEMBER 1976

Station	Shannon Index	Richness	Evenness	Number of Species
		October - 1974		
20	2.76	1.85	.74	14
21	2.43	1.41	.71	11
22	1.71	1.90	.42	19
		December - 1974		
20[a]				
21[a]				
22[a]				
		April - 1975		
20	2.74	1.62	.69	16
21	2.42	1.35	.65	13
22	2.81	2.15	.65	20
		June - 1975		
20	2.81	1.57	.79	12
21	2.97	2.14	.70	19
22	1.37	.67	.60	5
		July - 1975		
20	1.74	1.21	.53	10
21	2.65	1.52	.75	12
22	2.35	1.29	.76	9
		August - 1975		
20	2.51	1.10	.85	8
21	3.03	1.58	.87	11
22	2.85	1.58	.83	13
		October - 1975		
20	2.47	1.50	.65	14
21	2.42	1.92	.62	15
22	2.99	1.45	.90	10
		November - 1975		
20	2.76	1.42	.81	11
21	2.55	1.49	.73	12
22	2.06	1.02	.73	7
		April - 1976		
20	2.17	1.20	.65	10
21	2.38	.98	.81	8
22	2.19	.96	.76	7
		June - 1976		
20	2.45	1.62	.65	14
21	2.74	2.04	.64	19
22	2.97	1.65	.79	14
		July - 1976		
20	2.74	1.95	.67	17
21	3.21	2.19	.77	18
22	1.95	1.29	.55	12
		August - 1976		
20	2.19	1.34	.59	13
21	1.45	1.01	.47	9
22	2.69	1.67	.71	14

[a]Stations were frozen at time of sampling

and Oligochaeta (Table 2.58). Plecoptera comprised 15 percent of the community in October 1974 and the Simuliidae made up 18 percent in June 1976. Major ephemeropteran genera included Ephemerella, Rhithrogena, Tricorythodes, and Baetis. The chironomids were primarily represented by Orthocladiinae and Chironominae. Orthocladiinae genera included Orthocladius, Eukieferiella, and Cricotopus. Parakiefferiella, Polypedilum, and Rheotanytarsus were the most common genera of Chironominae. Naididae and Tubificidae were the most abundant oligochaetes.

Diversity indices for the back channel habitats were reported in Table 2.59. Shannon index values on the White River stations were relatively high (above three at most stations and the number of taxa averaged about 20. Although there were fewer individuals in the White River back channels than at spring brooks and Yellow Creek stations, they were more evenly distributed. The White River community was not dominated by a few taxa, as was the case in Yellow Creek.

b. Open Channel. Thirty-nine families and 96 genera were identified from collections in the open channel habitat. Densities of the most abundant taxa are recorded in Table 2.60. As in the back channel habitat, the open channel habitat of the White River has a heterogeneous substrate which favors a more evenly distributed and diverse community than in other habitats in the study area. At the river edges, cobbles and gravel are common, whereas larger cobbles and boulders occur near the center. During low flow periods, sand, silt, and some detritus are deposited in areas with low current velocity. Hynes (1970) states that one of the major factors controlling the occurrence of lotic animals is the substratum. This undoubtedly is one of the major reasons for differences in the species composition of pond, spring brook, creek, and river habitats. Mayflies, caddisflies, and, to some extent, stoneflies were more common in the White River than in these other habitats.

Ames and Frank (1976) describe the White River as a clean river and note that Simuliidae are most abundant in the headwaters of the White River and are less abundant at the lower stations. They attribute this to the increased turbidity below Meeker.

TABLE 2.58
MOST ABUNDANT MACROINVERTEBRATE TAXA[a] OF BACK CHANNEL HABITATS DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976. (ORGANISMS $1m^2$)

Taxon	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
Nematoda	61	Frozen	93	Qualitative	8	18	8	12	13	3	4	1
Tubificidae	107		691		398	105	260	18	217	124	424	176
Naididae	1,694		154		5	1,086	339	108	66	20	34	238
Baetis	182		98		0	29	131	5	7	37	4	7
Rhithrogena	326		31		5	62	484	139	61	93	272	345
Ephemerella	94		832		5	101	888	783	776	336	40	83
Tricorythodes	66		78		3	79	113	44	27	13	923	351
Hydropsyche	309		64		2	320	948	467	43	21	136	64
Chironomidae	645		1,427		47	566	902	937	432	775	109	315
Simuliidae	70		4		0	62	14	43	0	522	69	2
Total (All Species)	5,032		3,846		491	3,103	5,148	4,033	1,824	2,977	3,636	3,363

[a] 10 most abundant taxa over the study period

TABLE 2.59

SUMMARY OF DIVERSITY INDICES FOR BENTHIC MACROINVERTEBRATES (WHITE RIVER-BACK CHANNEL) OCTOBER-NOVEMBER 1974 AND AUGUST-SEPTEMBER 1976

Station	Shannon Index	Richness	Evenness	Number of Species
		October - 1974		
23[a]				
27	3.61	2.58	.83	20
28	2.53	2.75	.54	25
29	3.41	3.03	.72	27
33[c]				
		December - 1974		
23[b]				
27[b]				
28[b]				
29[b]				
33[a]				
		April - 1975		
23	3.50	3.07	.74	27
27	3.04	2.02	.79	17
28	2.87	3.42	.78	31
29	3.49	3.44	.71	30
33	3.08	2.24	.73	19
		June - 1975		
23[a]				
27[a]				
28[a]				
29[a]				
33[a]				
		July - 1975		
23	1.29	1.00	.38	3
27	1.72	.59	.97	4
28	2.62	1.68	.73	12
29	1.37	.80	.53	7
33	1.91	.65	.97	4
		August - 1975		
23	3.76	3.41	.77	29
27	3.28	2.44	.78	19
28	2.49	3.01	.53	25
29	3.73	3.16	.79	26
33	3.01	3.05	.65	26
		October - 1975		
23	3.35	2.77	.75	24
27	4.04	3.41	.83	29
28	3.01	2.31	.73	18
29	3.58	3.06	.73	30
33	3.37	2.68	.75	23
		November - 1975		
23	3.40	2.28	.80	19
27	3.05	2.59	.67	23
28	3.01	2.10	.75	16
29	2.92	2.38	.66	22
33	3.65	2.65	.81	23
		April - 1976		
23	2.95	2.68	.66	22
27	2.40	2.26	.57	19
28	2.93	1.63	.83	12
29	2.94	1.74	.79	14
33	2.86	2.07	.72	16
		June - 1976		
23	2.52	1.92	.64	16
27	3.28	2.93	.71	24
28	3.71	2.56	.85	21
29	2.69	1.71	.69	15
33[a]				
		July - 1976		
23	3.03	2.60	.69	22
27	2.73	2.09	.66	18
28	2.47	2.08	.99	18
29	3.47	3.02	.73	27
33	2.87	1.88	.75	15
		August - 1976		
23	3.46	3.43	.71	30
27	3.72	2.93	.81	24
28	3.17	2.60	.72	22
29	3.67	2.77	.81	23
33	3.35	2.59	.76	21

[a]Stations were unable to be sampled due to depth, current velocity, and type of substrate

[b]Stations were frozen at time of sampling

[c]Stations were not established at this collection date

TABLE 2.60
MOST ABUNDANT MACROINVERTEBRATE TAXA[a] OF OPEN CHANNEL HABITATS DURING RBOSP BASELINE STUDIES, OCTOBER 1974 TO AUGUST 1976. (ORGANISMS $1m^2$)

Taxon	1974		1975						1976			
	Oct.	Dec.	Apr.	Jn.	Jy.	Aug.	Oct.	Nov.	Apr.	Jn.	Jy.	Aug.
Nematoda	7	Frozen	46	3	18	21	16	20	55	30	12	7
Tubificidae	79		247	29	59	40	132	6	425	324	333	64
Naididae	1,372		76	3	10	995	267	71	27	62	103	222
Baetis	92		131	65	0	63	70	7	13	4	0	11
Rhithrogena	20		26	16	18	510	675	300	12	14	206	149
Ephemerella	808		1,259	52	10	90	1,524	807	1,523	181	72	62
Tricorythodes	328		232	0	2	65	202	27	65	50	1,987	317
Hydropsyche	355		97	26	14	498	686	425	216	34	46	57
Chironomidae	1,530		1,584	26	28	397	898	1,120	1,203	895	423	310
Simuliidae	7		4	699	0	53	5	23	0	43	46	76
Total (All Speices)	5,476		4,125	1,043	210	3,857	5,260	4,185	4,042	2,149	5,454	2,575

[a] 10 most abundant taxa over the study period

RBOSP studies indicate that Naididae and Tubificidae (Oligochaeta) and the Chironomidae and Simuliidae (Insecta) are important components of the open channel habitats. Densities recorded in Table 2.60 indicate that Naididae dominated the Oligochaeta from August through October and Tubificidae dominated from April through July. Major Chironomidae genera included Orthocladius, Eukiefferiella, and Parakiefferiella (Orthocladiinae) and Microtendipes, Rheotanytarsus, Paratanytarsus, and Polypedilum (Chironominae) during the two years of study. In June 1975, Simuliidae comprised 67 percent of the open channel community. Differences in emergence patterns for the two years were similar to those described for spring brooks.

Diversity indices for the open channel river habitats are reported in Table 2.61. Shannon index values for the open channels were generally higher than in the back channel values. One possible explanation for this is difference in substrates. The open channel substrate consists of boulders mixed with the cobble and rubble, except at Stations 34 and 35 where the substrate is composed of constantly shifting small particles. These substrates tend to inhibit propagation of burrowing organisms. In both 1975 and 1976, the number of taxa and the richness index were lower at the lower stations on the White River than at the upper stations for both habitat types. This was probably because of substrate differences.

In addition to the more abundant taxa in each habitat, there are many common or rare taxa which occur only in certain habitat types. The spring brooks supported more genera of Tipulidae than other habitats in the study area. Genera of Podonominae (a subfamily of Chironomidae) occurred only in the spring brooks. Other Chironomid genera unique to the spring brooks included Prodiamesa, Pseudodiamesa, Gymnometriocnemus, Krenosmittia, Paraorthocladius, Chironomus plumosus type, and Endochironomus. Many taxa, including eight genera of coleopterans, were found exclusively in the spring brooks and ponds. Hemipterans were found most commonly in the ponds, although this may be the result of the collection procedures used. The mayfly Epeorus, the caddisflies Hesperophylax and Limnephilus, the Chironomidae genera of Chaetocladius, Diplocladius, Metriocnemus and Paratendipes, and Stratiomyidae genera of Euparphyus and

TABLE 2.61

SUMMARY OF DIVERSITY INDICES FOR BENTHIC MACROINVERTEBRATES
(WHITE RIVER-OPEN CHANNEL) OCTOBER-NOVEMBER 1974 AND AUGUST-SEPTEMBER 1976

Station	Shannon Index	Richness	Evenness	Number of Species
		October - 1974		
24[a]	3.40	2.80	.73	25
25[a]				
26				
30[c]				
31[c]				
32[c]				
34[c]				
35[c]				
		December - 1974		
24[a]				
25[a]				
26[a]				
30[b]				
31[b]				
32[b]				
34[a]				
35[a]				
		April - 1975		
24	3.32	2.79	.71	26
25	3.04	2.83	.66	24
26	3.21	2.66	.71	24
30	3.19	2.58	.71	23
31	3.12	2.40	.72	20
32	3.08	2.32	.71	20
34	2.18	1.54	.70	13
35	2.79	2.26	.67	18
		June - 1975		
24[a]				
25[a]				
26[a]				
30	1.61	1.19	.50	9
31	2.69	1.26	.89	9
32[a]				
34[a]				
35[a]				
		July - 1975		
24	3.32	1.93	.93	13
25[a]				
26	3.06	1.70	.90	11
30	2.28	.90	.98	5
31[a]				
32	1.79	.64	.93	4
34	1.05	.37	.58	2
35	2.07	.66	.90	4
		August - 1975		
24	2.72	3.25	.56	29
25[a]				
26	3.22	3.24	.66	28
30	3.24	2.94	.73	23
31	3.03	2.96	.65	25
32	3.62	3.14	.77	26
34	1.62	1.75	.41	15
35	3.35	2.51	.75	23

TABLE 2.61 (Continued)

Station	Shannon Index	Richness	Evenness	Number of Species
		October - 1975		
24	3.44	3.10	.73	27
25[a]				
26	3.62	3.45	.72	32
30	3.62	3.11	.77	25
31	3.30	2.67	.72	24
32	3.80	2.97	.82	25
34	2.18	2.20	.51	20
35	3.06	2.43	.68	22
		November - 1975		
24	3.29	2.86	.71	26
25[a]				
26	3.28	2.86	.70	26
30	3.87	2.96	.83	25
31	3.47	2.32	.81	20
32	3.98	3.18	.84	27
34	2.26	1.47	.65	12
35	3.41	2.40	.77	22
		April - 1976		
24	3.00	2.78	.65	25
25	2.58	2.86	.55	26
26	2.52	2.46	.57	22
30	3.40	3.01	.72	26
31	3.09	2.78	.68	24
32	2.81	2.48	.63	22
34	2.96	1.70	.82	13
35	2.54	1.77	.67	14
		June - 1976		
24[a]				
25	3.89	2.99	.85	24
26	3.80	2.97	.84	23
30[a]				
31	3.61	2.56	.86	20
32	3.45	2.61	.78	22
34[a]				
35[a]				
		July - 1976		
24	3.27	3.09	.68	28
25	2.89	2.43	.67	21
26	3.26	3.31	.67	30
30	2.99	2.50	.69	21
31	2.82	3.21	.58	30
32	3.20	3.02	.67	28
34	2.98	2.26	.70	20
35	3.28	2.60	.73	22
		August - 1976		
24	3.67	3.00	.80	24
25	3.32	2.38	.78	19
26	3.59	2.30	.82	19
30	3.74	2.85	.84	22
31	3.64	3.19	.77	27
32	3.83	2.98	.84	25
34	3.05	2.47	.70	21
35	3.13	2.47	.72	21

[a]Stations were unable to be sampled due to depth, current velocity, and type of substrate
[b]Stations were not established at time of collection
[c]Stations were frozen at the time of sampling

Stratiomys were also collected only in spring brooks and ponds. More genera of Tanypodinae (subfamily of Chironomidae) were found in the spring brooks and ponds than elsewhere. Psectrocladius and Lauterborniella were unique to the ponds.

The White River supported several genera of mayflies not found in the Yellow Creek drainage. These included Ameletus, Centroptilum, Dactylobaetis, Lachlania, Rhithrogena, Paraleptophlebia, Traverella albertana, Choroterpes, and Ephoron. The stonefly Claassenia sabulosa and the caddisflies Glossosomatidae, Agraylea, Mayatrichia, and Brachycentrus also occurred only in the river habitat. Dipterans unique to the White River included Monodiamesa, Potthastia, Cardiocladius, Mesosmitha, Nanocladius, Dicrotendipes, and Harnischia. The rhagionid Atherix variegata was collected only in the White River. Most dragonflies were collected in the White River, although damselflies were ubiquitous throughout the drainage, as were the Nematoda and Acari.

C. Food Habits

Different life stages of benthic organisms may exhibit different feeding habits. Opportunism, multitrophic level feeding, and changes in the niche at different life stages all contribute to the complexity of the food web of the Yellow Creek drainage.

Many of the adaptations shown by the aquatic insects in the study area deal with their food gathering habits. Both primary and secondary consumer levels were present and they fall into the general categories of shredders, collectors, scrapers, or predators, based on particle-size range and type of food as described by Cummins (1973).

The most common family of Diptera in the Yellow Creek drainage was the Chironomidae. Most of the chironomids may be classified either as carnivores or as algal-detrital feeders (collectors and scrapers). Almost all midges are opportunistic in their feeding habits. Thus, algae is almost always a dietary component of predatory species and algal-detritus feeders sometimes take in

small animals (Coffman, Cummins and Wuycheck 1971).

All species of Tanypodinae, as well as a few genera belonging to the Chironomini, are predators (Oliver 1971). Diamesinae larvae feed primarily on diatoms. Most larvae of Orthocladiinae and Chironominae are algal or algal-detrital feeders. Rheotanytarsus builds a tube with a number of outwardly pointed arms; the larvae spin strings of saliva between these arms to catch detritus and diatoms (Hynes 1970). Other larvae of the Chironominae spin nets within their tubes and draw water in by body undulations (Oliver 1971). Simulium larvae have large cephalic fans with which they strain detritus and diatoms from the moving water.

Mayflies are primarily herbivorous (Gilpen and Brusven 1970). Rhithrogena feeds on periphyton. Individuals of this genus have a broad hairy labrum and labial and maxillary palps which are armed with stout bristles to enable them to brush the algae off the substrate. Nymphs of Baetis feed primarily on detritus and diatoms together with small amounts of filamentous algae and higher plants (Gilpen and Brusven 1970). Chapman and Demory (1963) state that Baetis feed upon algae, chiefly diatoms, in spring but detritus in other seasons. Gilpen and Brusven (1970) found that nymphs of six species of Ephemerella fed primarily on detritus, diatoms and desmids, and filamentous algae. Caenidae are described as sediment or deposit feeders that consume fine particulate detritus, and as organic scrapers, eat periphyton (Cummins 1973). Tricorythodes minutus is reported to eat consistently more detritus than anything else (Koslucker and Minshall 1973). One species of Heptagenia is recorded as being an algal-detritus feeder (Gilpen and Brusven 1970).

Individuals of the family Hydropsyschidae are net-builders. Nets are placed only on solid substrates in running water and only in the summer in temperate climates (Hynes 1970). Small animals and pieces of vegetation are periodically taken from the net. Not all net-builders are omnivorous. Koslucker and Minshall (1973) found Hydropsyche occidentalis to be a herbivore. Other studies have shown Hydropsyche species to take in considerable amounts of animal matter (Coffman, Cummins and Wuycheck 1971). Hydroptilidae are

herbivores which feed on diatoms and other algae. Limnephilidae consume a preponderance of plankton, sessile diatom growths, and other small organisms (Ross 1944). Cummins (1973) found certain Limnephilidae to be large particle detritivores that shred decomposing vasular plant tissue. Brachycentrus attaches its case to the tops of stones and spreads its hairy meso-and metathoracic legs to catch particles in the water. The larvae cleans the particulate matter from these legs with the prothoracic legs and consumes this material.

Odonata are predaceous and the labium is modified for capturing prey. Plecoptera are highly opportunistic and will feed on whatever is available (Richardson and Gaufin 1971). Taxa belonging to the families Perlidae and Perlodidae prefer to eat animal matter.

Oligochaetes are commonly classified as detritus feeders. A study by Wavre and Brinkhurst (1971) indicates that tubificids feed extensively on bacteria in the sediments. This study also indicates that different species of tubificid worms may feed on different bacteria species. Naidids are usually phytophagus, but the genus Chaetogaster may occasionally be carnivorous, feeding on other naidids, Rotatoria, Cladocera, Ostracoda, and mites (Monakov 1972).

D. Summary

The organisms most often encountered throughout the Yellow Creek drainage were the Diptera (Chironomidae, Simuliidae, Ceratopogonidae, Tipulidae and Anthomyiidae), Oligochaeta, Ephemeroptera (Baetis), Plecoptera (Capnia), Trichoptera (Hydroptilidae and Hesperophylax), Odonata (Coenagrionidae), and Coleoptera (Dytiscidae). Organisms occasionally collected in the Yellow Creek drainage were Ephemeroptera (Callibaetis and Caenis), Diptera (Psychodidae, Stratiomyidae, Tabanidae, and Empididae), Gastropoda, Hirudinea (Helobdella stagnalis), and Hyalella azteca. Benthic invertebrates collected rarely in the Yellow Creek drainage were Ephemoroptera (Epeorus and Tricorythodes), Odonata (Aeshnidae and Gomphidae), Coleoptera (Gyrinidae, Haliplidae,

Hydraenidae, Hydrophilidae, Elmidae, and Dryopidae), Trichoptera (Hydropschye and Limnephilus), Diptera (Thaumaleidae and Dixidae), Hydra and Collembola.

In the White River Stations, Ephemeroptera, Diptera, and Oligochaeta were the dominant groups. There was also a greater diversity in the mayflies, caddisflies, and stoneflies in the White River than in other habitats. Ephemeroptera included primarily Ephemerella, Rhithrogena, and Baetis. Moderate numbers of Heptagenia and Tricorythodes were recorded. Ameletus, Lachlania, Centroptilum, Dactylobaetis, Paraleptophlebia, Caenis, Brachycercus, and Ephoron were rare.

The caddisflies were represented mainly by the Hydropschidae. Occasionally numbers of Hydroptilidae and Glossosomatinae were taken. Oecetis and Brachycentrus were sparse. Common Plecoptera were Isogenoides, Isoperla, and Claassenia. Brachyptera and Capniidae were occasionally collected. Small numbers of Odonata (Ophiogomphus), Lepidoptera (Pyralidae), Acari, Collembola, Hemiptera (Corixidae), Coleoptera (Elmidae), and Diptera (Ceratopogonidae, Tipulidae, Simuliidae, Rhagionidae, and Empididae) were collected. Fewer dominant chironomid taxa occurred in the White River than in the Yellow Creek drainage.

Oligochaeta were represented by seven families: Tubificidae, Naididae, Enchytraeidae, Lumbriculidae, Haplotaxidae, Lumbricidae, and Aeolostomatidae. Tubificidae, Naididae, and Enchytraeidae composed the bulk of the oligochaete populations of the RBOSP site. In general, the Naididae and Enchytraeidae were abundant in the spring brooks, while Tubificidae and Naididae occurred in Yellow Creek and White River stations. Only one specimen of the family Aeolostomatidae was collected. These worms have been characterized as fragile worms, mostly less than 2mm long (0.08 in) and are not usually found in field collections unless specifically searched for (Brinkhurst and Cook 1974). The family Lumbricidae included all specimens which had a thick muscular body wall and two chaetae per bundle. These specimens could possibly belong to the genus Sparoanophilus, as the genus has been reported as being the most common limnetic megadrile in North America (Brinkhurst and Jamieson 1971). The Haplotaxidae

occurred only at Stations 1 and 2 in the spring brook stations. They are known mainly from underground waters and where ground water seepages enter a stream (Brinkhurst 1966a,b). The family Lumbriculidae were present in lower spring brook stations, Yellow Creek, and certain White River stations. This group has been characterized as being present in stony trout streams (Brinkhurst 1966a). The Enchytraeidae were most common at spring brook stations. Most species in this family are terrestrial in habit (Brinkhurst 1963), suggesting that their abundance in the spring brook stations is possibly attributable to their ability to survive when these streams dry up in the summer. The family Naididae was fairly abundant throughout the study area. Brinkhurst (1966a) has characterized the family as occurring in rapidly flowing streams. They are small and fragile and occasionally pass through the mesh sieves (0.5mm) of conventional benthic surveys (Howmiller and Beeton 1970). Thus, the probability of more species being present than is reported here is high. The Tubificidae, long characterized as being tolerant of environmental stress (Brinkhurst and Jameison 1971), were quite abundant at Station 5, Yellow Creek and White River stations. Tubificids have been known to feed primarily on the bacteria contained in organic matter (Brinkhurst,et al. 1972), which suggest a possible reason for large occurrence of tubificids at Station 5. There is much aquatic vegetation in this area which would form the detritus upon which develops the bacterial biomass needed to support large populations of these worms. Reasons for abundance of tubificids in other sampling areas are unknown.

VI. FISH

A. Species Composition

During the two-year RBOSP baseline study, a total of 4,229 fish, comprising 15 species and one hybrid form, was captured in the White River and Yellow Creek (Table 2.62). The most abundant species were, in descending order, speckled dace, flannelmouth sucker, mottled sculpin, fathead minnow, and bluehead sucker. A complete list of fish species appears in RBOSP Progress Report 10. Common and scientific names of fishes found in the area are shown in Table 2.62.

The fish catch composition during the second year was generally similar to that recorded for the first year (Table 2.63). The only important difference was the large decrease in catch of fathead minnows during the second year. All other species were generally captured in the same proportions in both years. Four fewer species were captured during the second year. However, the missing species, cutthroat and rainbow trout, mountain sucker and black bullhead, were rare in the first year's catch, so their absence from the second year's catch is not unexpected.

The dominant "large fish" of the RBOSP study area, the flannelmouth and bluehead suckers, occurred in similar proportions in both years; the flannelmouth sucker was about 3.5 times more abundant than the bluehead sucker. Although possible selective sampling techniques or habitat affinities for each species could affect results, this ratio probably reflects actual abundance. Holden and Stalnaker (1975) found that the flannelmouth sucker was almost six times more abundant than the bluehead sucker in the Upper Colorado River and its tributaries.

Colorado State University (CSU) personnel conducted sampling in the White River during 1975 and early 1976 (see Prewitt et al. 1976, and Prewitt and Carlson 1975). One of their stations was located approximately 19 km upstream from Yellow Creek. With one exception, they caught the same fish species found during the RBOSP studies. They caught more mountain whitefish but fewer mottled sculpins than were taken during the RBOSP study. The CSU group also took a creek chub, Semotilus atromaculatus, a species not captured during the RBOSP

TABLE 2.62
LIST OF FISH SPECIES CAPTURED AT THE RBOSP
SITE DURING THE PERIOD OCTOBER 1974 THROUGH
SEPTEMBER 1976.

Common Name[1]	Scientific Name[1]	Oct. '74 Sept. '75	Oct. '75 Sept. '76
Cutthroat trout	Salmo clarki	X	
Brown trout	Salmo trutta	X	X
Rainbow trout	Salmo gairdneri	X	
Mountain whitefish	Prosopium williamsoni	X	X
Roundtail chub	Gila robusta	X	X
Speckled dace	Rhinichthys osculus	X	X
Fathead minnow	Pimephales promelas	X	X
Red shiner	Notropis lutrensis	X	X
Carp	Cyprinus carpio	X	X
Flannelmouth sucker	Catostomus latipinnis	X	X
Bluehead sucker	Catostomus discobolus	X	X
Mountain sucker	Catostomus platyrhynchus	X	
Flannelmouth X Bluehead	C. lattipinnis X C. discobolus	X	X
Channel catfish	Ictalurus punctatus	X	X
Black bullhead	Ictalurus melas	X	
Mottled sculpin	Cottus bairdi	X	X

[1]Common and scientific names after Bailey, et al. 1970

TABLE 2.63

NUMBER OF FISH CAPTURED BY SAMPLING DATE FOR THE RBOSP DURING THE FIRST AND SECOND YEAR BASELINE STUDIES, OCTOBER 1974-SEPTEMBER 1975 AND OCTOBER 1975-SEPTEMBER 1976

Species	October		November	April		June		July		September		Total	
	1974	1975	1975	1975	1976	1975	1976	1975	1976	1975	1976	1974-75	1975-76
Cutthroat trout	-	-	-	-	-	1	-	-	-	-	-	1	-
Brown trout	1	1	-	1	-	-	-	-	-	1	-	3	1
Rainbow trout	1	-	-	4	-	-	-	-	-	-	-	5	-
Mountain whitefish	7	9	9	2	9	-	-	-	-	8	-	17	27
Roundtail chub	-	1	-	1	1	10	3	5	2	5	27	21	34
Speckled dace	126	71	27	21	20	238	131	48	163	392	381	825	793
Fathead minnow	90	1	1	10	1	54	1	5	5	150	48	309	57
Red shiner	-	-	-	-	1	-	-	1	-	10	4	11	5
Carp	-	-	-	-	-	1	-	3	2	23	49	27	51
Flannelmouth sucker	58	4	14	66	54	128	49	109	-	162	101	523	408
Bluehead sucker	26	5	3	14	3	38	9	17	41	64	54	159	115
Mountain sucker	-	-	-	-	-	-	-	1	-	1	-	2	-
Flannelmouth x Bluehead	-	1	-	1	-	-	-	-	186	2	-	3	1
Channel catfish	-	1	-	-	-	-	-	-	-	1	-	1	1
Black bullhead	-	-	-	-	-	-	-	1	-	-	-	1	-
Mottled sculpin	233	97	9	28	3	11	20	11	75	130	211	413	415
Totals	542	191	63	148	92	481	213	201	474	949	875	2,321	1,908

studies. This is an introduced minnow from east of the Rocky Mountains that has been recorded from several locations in the Green River system, but never in abundance.

No threatened or endangered fish species were encountered during the two-year RBOSP baseline study. However, Everhart and May (1973) reported capturing the Colorado squawfish (Ptychocheilus lucius) and bonytail chub (Gila elegans) near the RBOSP study area in 1969. The Colorado squawfish is on both the Colorado and federal endangered species lists and the bonytail is on the Colorado list (Johnson 1976). Neither of these species has been recently encountered by CSU personnel in their current White River studies (see Prewitt et al. 1976) nor by the RBOSP study group. It is important to note that the Bureau of Land Management has designated the White River from its mouth up to the Yellow Creek-Piceance Creek area as having "suspected populations" and being "potential habitat" for three threatened-endangered species (Johnson 1976). These include the two species mentioned above as well as the humpback sucker (Xyrauchen texanus). The humpback sucker is on the Colorado endangered species list (Johnson 1976).

B. Relative Abundance and Distribution

The distribution and size of the second year's fish catches are presented in Tables 2.64 and 2.65. The data in Table 2.65 appear to fall into three general categories: 1) small catches, Yellow Creek Stations 20, 21, and 22; 2) intermediate catches, main channel White River Stations 24, 25, 26, 30, 31, 32, 33, 34, and 35; and 3) large catches, back channel White River Stations 23, 27, 28, and 29.

A comparison of these data with the previous year's catch data (RBOSP Aquatic Studies Annual Report 1976, Figures 3-8-26, 27, 28) reveals, with few exceptions, similar distribution of catches in both years. Catches from Yellow Creek were low in both years, with the exception of Station 22 during the first year. This high catch at Station 22 was due to a large concentration of small fish in June of 1975 when high water backed up into the station.

TABLE 2.64
MEAN NUMBER, WEIGHT AND NUMBER OF SPECIES OF FISH CAPTURED PER SAMPLING PERIOD AT THE RBOSP SITE
(OCTOBER 1975 - SEPTEMBER 1976)

Station	No. Samples	No. Fish	Weight (Grams)	No. Species
20	4	0.3	0.6	0.3
21	5	0.2	0.1	0.2
22	5	0.4	0.2	0.4
23	5	23.2	1,728.9	3.8
24	5	22.0	39.3	1.8
25	6	6.2	587.9	1.2
26	6	23.2	94.7	2.2
27	6	52.2	2,236.2	4.3
28	6	34.0	1,867.3	4.3
29	6	28.2	720.6	3.8
30	5	11.4	650.4	1.8
31	6	6.5	611.0	2.2
32	6	12.8	236.4	3.0
33	5	5.0	635.8	2.2
34	5	15.0	959.1	2.6
35	6	24.8	62.0	2.2

TABLE 2.65
NUMBER, WEIGHT AND NUMBER OF SPECIES OF FISH CAPTURED DURING EACH SAMPLING PERIOD AT EACH STATION AT THE RBOSP SITE, OCTOBER 1975 - SEPTEMBER 1976.

	October 13-17, 1975			November 17-20, 1975		
Station	No. fish	Weight(gm)	No. species	No. fish	Weight(gm)	No. species
20	0.0	0.0	0.0		NOT FISHED	
21	0.0	0.0	0.0		NOT FISHED	
22	0.0	0.0	0.0		NOT FISHED	
23	17.0	171.5	4.0		NOT FISHED	
24	7.0	41.8	2.0	2.0	22.6	1.0
25	7.0	52.6	2.0	0.0	0.0	0.0
26	33.0	156.3	2.0	8.0	30.8	2.0
27	8.0	495.2	4.0	4.0	1,885.0	2.0
28	8.0	26.0	3.0	12.0	6,061.9	4.0
29	42.0	332.7	5.0	14.0	125.4	5.0
30	4.0	28.0	1.0	0.0	0.0	0.0
31	13.0	127.2	2.0	4.0	1,618.7	3.0
32	8.0	56.2	3.0	1.0	32.9	1.0
33	4.0	39.0	3.0	0.0	0.0	0.0
34	31.0	700.1	4.0	2.0	20.0	2.0
35	10.0	68.8	3.0	0.0	0.0	0.0
	April 12-16, 1976			June 21-25, 1976		
20	1.0	2.4	1.0		No sample	
21	0.0	0.0	0.0	1.0	0.5	1.0
22	1.0	0.6	1.0	1.0	0.6	1.0
23	8.0	3,253.5	3.0	15.0	1,042.6	4.0
24	0.0	0.0	0.0		NOT FISHED	
25	2.0	1,215.0	1.0	3.0	2,075.0	1.0
26	0.0	0.0	0.0	7.0	180.9	2.0
27	46.0	4,633.0	6.0	11.0	2,808.0	4.0
28	8.0	26.0	3.0	18.0	2,103.7	5.0
29	0.0	0.0	0.0	38.0	1,989.4	4.0
30	5.0	3,009.0	2.0		NOT FISHED	
31	2.0	1,107.0	2.0	16.0	777.5	2.0
32	4.0	910.0	4.0	17.0	358.0	5.0
33	9.0	2,040.7	3.0		NOT FISHED	
34	5.0	2,573.0	1.0		NOT FISHED	
35	0.0	0.0	0.0	1.0	8.1	1.0

TABLE 2.65 (Continued)

Station	August 2-6, 1976 No. fish	Weight(gm)	No. species	August 30 - September 3, 1976 No. fish	Weight(gm)	No. species
20	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0
23	7.0	1,975.0	3.0	69.0	2,202.0	5.0
24	19.0	21.7	3.0	82.0	110.6	3.0
25	0.0	0.0	0.0	25.0	185.0	3.0
26	37.0	66.9	4.0	54.0	133.5	3.0
27	12.0	2,447.3	3.0	232.0	1,148.6	7.0
28	14.0	1,309.9	4.0	144.0	409.4	8.0
29	20.0	1,797.3	5.0	55.0	78.8	4.0
30	15.0	165.6	4.0	33.0	49.6	2.0
31	2.0	14.2	2.0	2.0	21.3	2.0
32	22.0	16.3	3.0	25.0	45.1	2.0
33	5.0	1,035.0	2.0	7.0	64.1	3.0
34	9.0	1,172.5	3.0	28.0	330.1	3.0
35	56.0	24.6	3.0	82.0	270.5	6.0

The weights of catches taken in the White River back channel Stations 23, 27, 28 and, to a lesser degree, 29 were high both years. This is presumably due to more effective fishing in these slow-water areas, especially when blocked off, and possible congregation of fish in these areas. The mean number of species per sample was also highest at back channel stations. One back channel station (33) failed to yield large catches during the second year although it had done so during the first year. This was partially due to the inability to block this station off as successfully during sampling as had been done the previous year. In addition, fish apparently moved out of this area as the second summer progressed (Table 2.65).

In general, the distribution of fish catches during the second year of sampling paralleled those of the first year. Yellow Creek produced few fish. Back channel White River stations yielded the largest catches, due to the combination of greater sampling efficiency and possible congregation of fishes in these areas. The dearth of fishes in Yellow Creek is partly due to the scarcity of habitat. The stream is reduced to a series of isolated warm-water pools during much of the year. Also, the stream is constantly disturbed by cattle ranching activities.

C. Age and Growth

1. Flannelmouth Sucker

Length-frequency distribution analyses conducted on flannelmouth suckers captured during June-September 1975 and August-September 1976 are presented in Figures 2.28 to 2.31. Length-frequency plots for flannelmouth suckers captured in 1976 (Figures 2.30 and 2.31) include only 1976 young-of-year fish (i.e., Age Class 0). The single grouping on the August 2-6, 1976 length-frequency plot (Figure 2.30) probably represents fish hatched in June. The same age group appears at the left of the plot for August 30-September 3, 1976 (Figure 2.31). The modal length of these young-of-year fish increased from 28 to 55 mm in approximately one month.

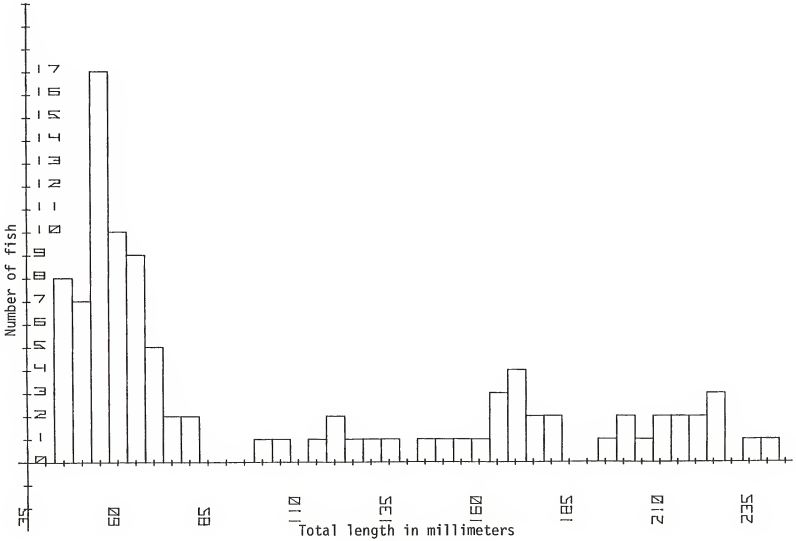


FIGURE 2.28

LENGTH-FREQUENCY DISTRIBUTION OF 98 FLANNELMOUTH SUCKERS COLLECTED JUNE 23-27, 1975

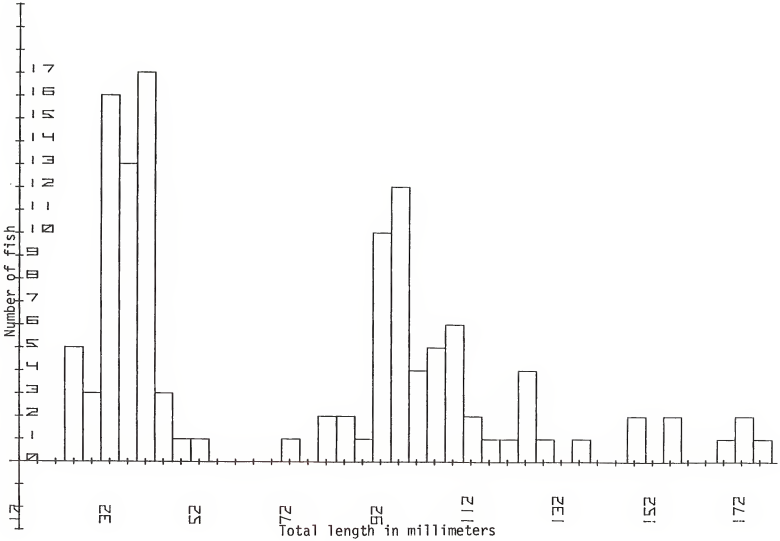


FIGURE 2.29

LENGTH-FREQUENCY DISTRIBUTION OF 120 FLANNELMOUTH SUCKERS COLLECTED SEPTEMBER 3-9, 1975

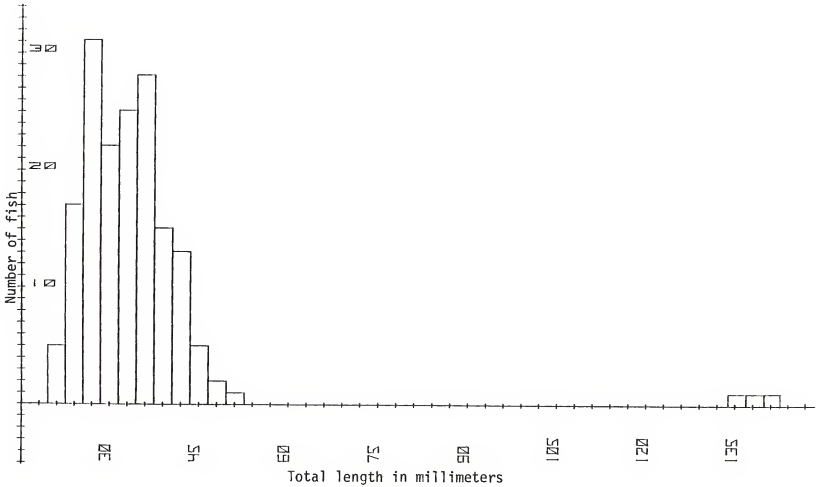


FIGURE 2.30

LENGTH-FREQUENCY DISTRIBUTION OF 145 FLANNELMOUTH SUCKERS
COLLECTED AUGUST 2-6, 1976

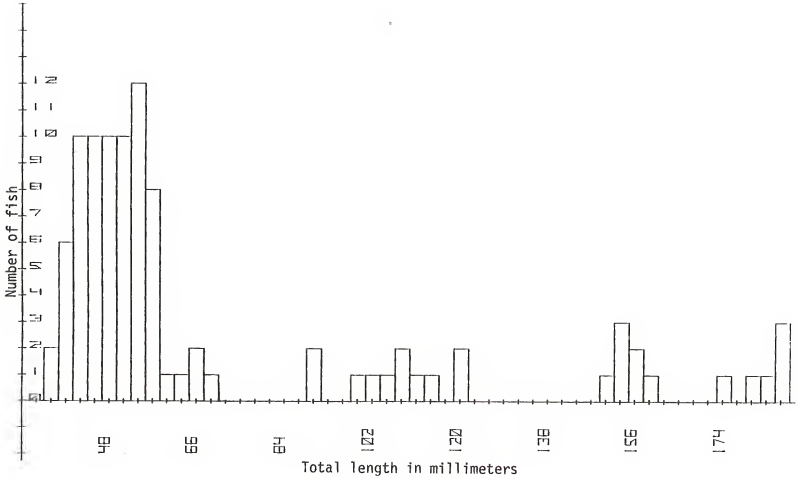


FIGURE 2.31

LENGTH-FREQUENCY DISTRIBUTION OF 83 FLANNELMOUTH SUCKERS
COLLECTED AUGUST 30-SEPTEMBER 3, 1976

June 1976 data were not plotted because of the small sample size, but the 13 specimens that were captured ranged from 14 to 21 mm (mean = 17 mm) in total length, indicating the length range of the new year class in June 1976. The average lengths of young-of-year flannelmouth suckers in late June, early August, and early September 1976 were 17 mm, 28 mm, and 55 mm.

A comparison of the 1976 length-frequency plots for flannelmouth suckers with the 1975 plots shows several differences. The 1975 plots for June 23-27 and September 3-9 had distinct peaks for Age Class I fish (Figures 2.28 and 2.29). Such peaks were not indicated on the 1976 plots, probably because of the small sample size. The modal length of August 30-September 3, 1976 young-of-year fish of 55 mm (Figure 2.31) is considerably larger than the 38-39 mm modal length for September 3-9, 1975 young-of-year fish (Figure 2.29). This is probably a result of earlier spawning in 1976. Spring runoff was much less in 1976 compared to 1975 and water temperatures increased much earlier than in 1975.

Although scale analysis data for flannelmouth suckers are presented (Table 2.66), these are tentative because of the difficulty involved in reading the scales and the fact that the scales of the flannelmouth sucker have never been validated as suitable age indicators. Utah State University personnel did not validate flannelmouth sucker scales as planned, but they believe that they can be read and are accurate age indicators (Wydoski, personal communication). Wick (1976), working in the Yampa and White Rivers, also reported that flannelmouth sucker scales were very difficult to read. In the present scale reading analysis, data for Age Classes 0-III are more reliable than those for older age classes.

Comparison of scale data between the first and second year of the study is only possible for a few dates and age classes. Mean total lengths of Age Class III fish in July were 263 mm and 248 mm for 1975 and 1976, respectively. Age Class I fish in September were 101 mm and 114 mm (mean length) for 1975 and 1976, respectively. The closeness of the values gives some support to the accuracy of the scale reading, at least for younger fish.

TABLE 2.66

RESULTS OF FLANNELMOUTH SUCKER AGE ANALYSIS BY SCALE READING.

	Number of Specimens	Mean Total Length(mm)	Length Range(mm)
October 13-17, 1975			
Age Class I	2	127	113 - 141
November 17-20, 1975			
Age Class 0	3	56	52 - 63
April 12-16, 1976			
Age Class I	5	96	91 - 105
Age Class II	8	118	99 - 175
Age Class III	2	150	135 - 165
Age Class IV	3	297	265 - 319
Age Class V	12	313	246 - 358
Age Class VI	9	413	321 - 491
Age Class VII	5	437	357 - 501
Age Class VIII	4	447	429 - 467
June 21-25, 1976			
Age Class I	3	98	81 - 123
Age Class III	3	268	142 - 471
Age Class IV	9	215	103 - 376
Age Class V	6	286	236 - 344
Age Class VI	9	363	230 - 471
Age Class VII	1	375	375
Age Class VIII	2	417	400 - 434
August 2-6, 1976			
Age Class II	2	138	134 - 141
Age Class III	4	248	247 - 249
Age Class IV	1	311	311
Age Class V	7	308	258 - 360
Age Class VI	2	415	380 - 450
Age Class VII	4	415	370 - 442
August 30-September 3, 1976			
Age Class 0	7	64	44 - 91
Age Class I	10	114	100 - 151
Age Class II	7	163	153 - 186
Age Class III	8	208	158 - 292
Age Class IV	1	398	398

2. Mottled Sculpin

Length-frequency data for mottled sculpin are presented in sequence from October 1974 through September 1976 (Figure 2.32 to 2.36). A definitive length-frequency analysis of mottled sculpin was hampered by small sample sizes and, particularly, lack of random samples. The young-of-year, or Age Class 0, fish were insufficiently sampled. Bailey (1953) reported that small sculpins often frequent shallow, relatively quiet water near shores of streams. Since thorough coverage of this habitat was not part of the sampling program, the small sculpins may be inadequately represented.

The 60 mm and 88 mm peaks in the October 14-18, 1974 plot (Figure 2.32) represent Age Class I and II fish, respectively. These groupings correspond well to those of Bailey (1952) for Age Class I and II mottled sculpins from the West Gallatin River, Montana. The two peaks in the September 3-9, 1975 plot (Figure 2.33) were originally reported as Age Class 0 (34 mm peak) and Age Class I-older (76 mm peak) (RBOSP Aquatic Studies Annual Report 1976). However, after study of additional data, the 76 mm peak was designated Age Class II. The few fish comprising the 34 mm peak group may be precocious Age Class 0 fish or smaller Age Class I fish; the small number of fish involved precludes a definitive assignment of age.

The October 13-17, 1975 plot (Figure 2.34) is similar to the October 14-18, 1974 plot (Figure 2.32). Age Class II fish show a mode at 88 mm and Age Class I at 52 mm in October 1975.

The August 2-6, 1976 sample (Figure 2.35) was small and exhibits only one peak at 34 mm. Based on a probable hatching time in June or even July and on the data of Bailey (1952), these fish are probably Age Class I. The August 30-September 3, 1976 Age Class I peak (Figure 2.36) is at 45 mm, representing an average increase of 11 mm from the previous month. It appears reasonable to assume that this group (45 mm mode) increased to 50-60 mm by late October, 1976 and thus would have produced a plot similar to those of October 1974 and 1975 (Figures 2.32 and 2.34).

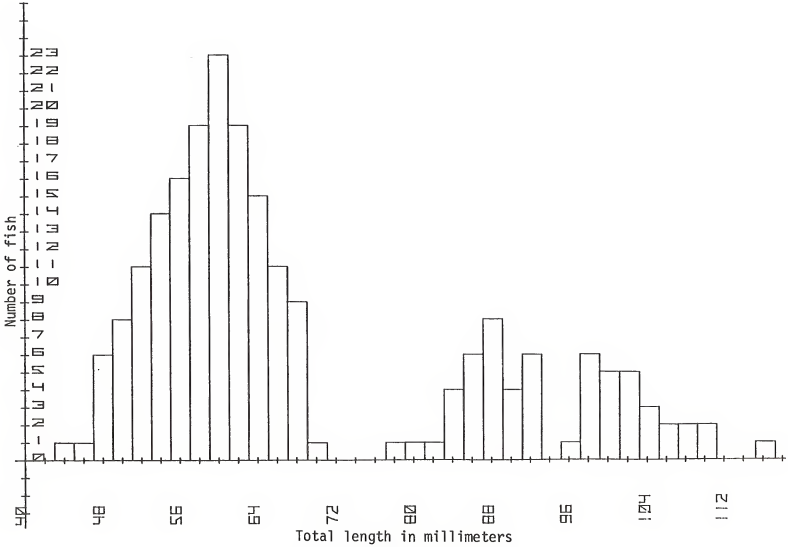


FIGURE 2.32

LENGTH-FREQUENCY DISTRIBUTION OF 212 MOTTLED SCULPIN COLLECTED OCTOBER 14-18, 1974

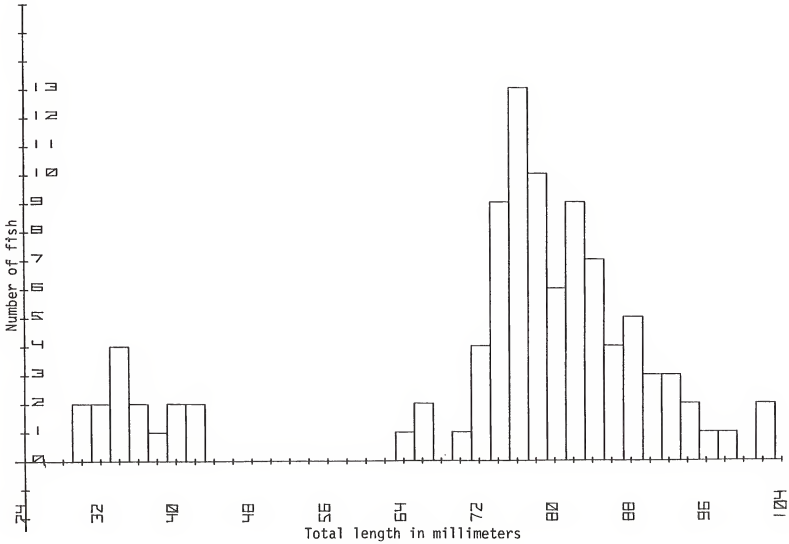


FIGURE 2.33

LENGTH-FREQUENCY DISTRIBUTION OF 98 MOTTLED SCULPIN
COLLECTED SEPTEMBER 3-9, 1975

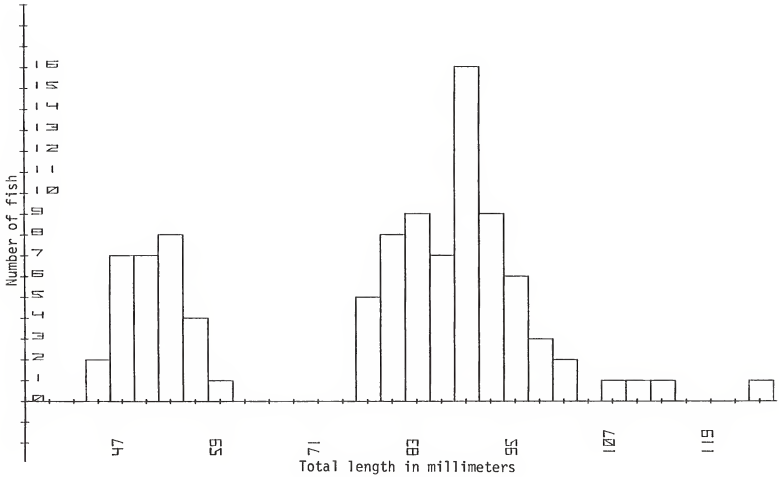


FIGURE 2.34

LENGTH-FREQUENCY DISTRIBUTION OF 98 MOTTLED SCULPIN
COLLECTED OCTOBER 13-17, 1975

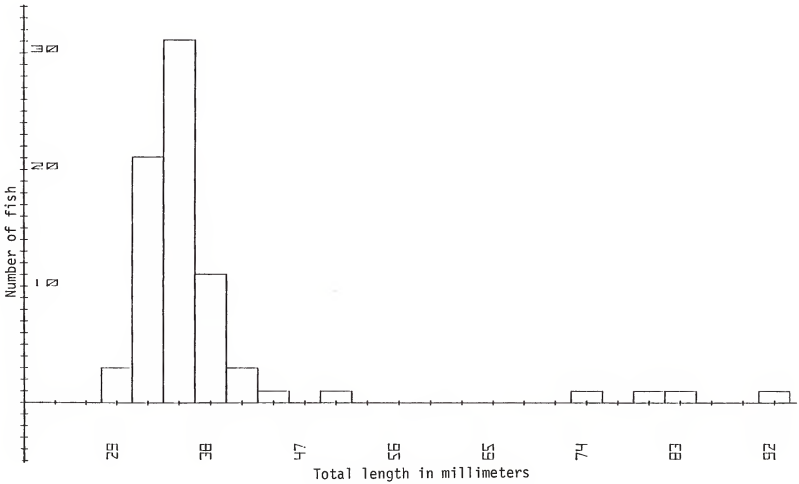


FIGURE 2.35

LENGTH-FREQUENCY DISTRIBUTION OF 75 MOTTLED SCULPIN
COLLECTED AUGUST 2-6, 1976

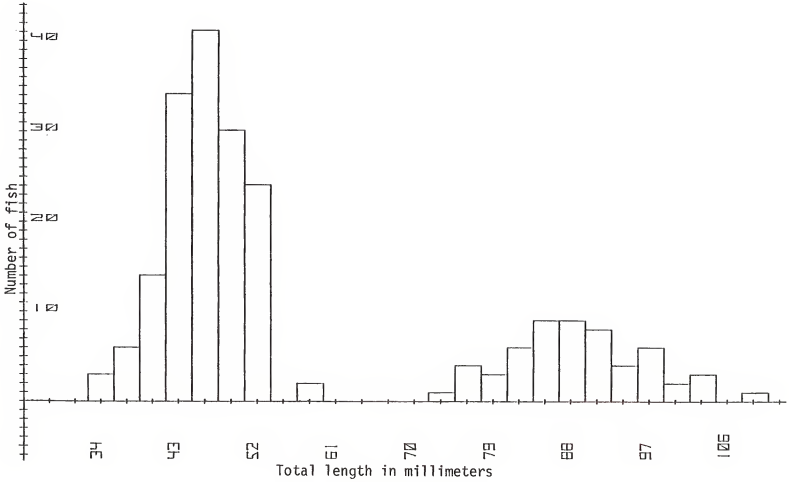


FIGURE 2.36

LENGTH-FREQUENCY DISTRIBUTION OF 210 MOTTLED SCULPIN
COLLECTED AUGUST 30-SEPTEMBER 3, 1976

In general, it appears that the growth history of mottled sculpins was similar in both years of the RBOSP baseline study.

3. Speckled Dace

Length-frequency plots for speckled dace from RBOSP collections on September 3-9, 1975, June 21-25, August 2-6, and August 30-September 3 are presented in Figures 2.37 through 2.40. The September 3-9, 1975 sample exhibited three distinct peaks at 36, 66, and 82 mm, corresponding to Age Class 0, I and, probably II. The corresponding plot for August 30-September 3, 1976 (Figure 2.40) shows only one distinct year class, that of Age Class 0 at 35 mm modal length, indicating a similar summer growth rate for young-of-year dace in both 1975 and 1976.

Each of the three 1976 plots shows only one clear age class. The 44 mm peak for June 21-25, 1976 (Figure 2.38) represents Age Class I fish. In early August (Figure 2.39), Age Class I fish are not represented but Age Class 0 fish appear with a 26 mm peak. By the end of August the Age Class 0 fish have increased to 35 mm modal length (Figure 2.40).

Growth of young-of-year speckled dace in the White River is similar to that of Trinity River, California speckled dace reported by Jhringran (1948, cited in Carlander 1969). However, growth of older age classes of White River specimens appears much greater than the growth of corresponding age classes reported by Jhringran (1948). As pointed out in RBOSP, Aquatic Studies Annual Report (1976), the White River speckled dace appear to grow to a much larger size than other populations reported in the literature.

D. Condition

Condition (K) factors are frequently used to describe the "plumpness" or "well-being" of fish (Carlander 1969). It is one type of index whereby any change in the relationship of the weight to the length of a fish, due to disease, insufficient food supply or other stresses, can be monitored and expressed quantitatively.

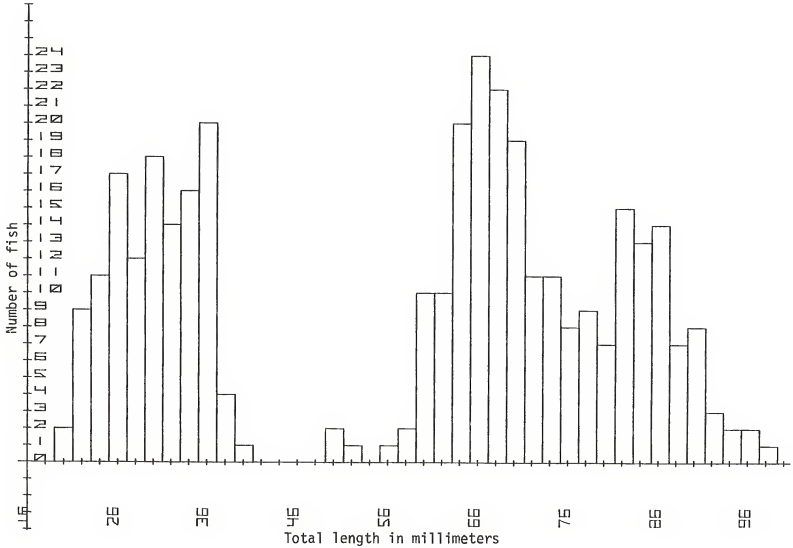


FIGURE 2.37

LENGTH-FREQUENCY DISTRIBUTION OF 346 SPECKLED DACE
COLLECTED SEPTEMBER 3-9, 1975

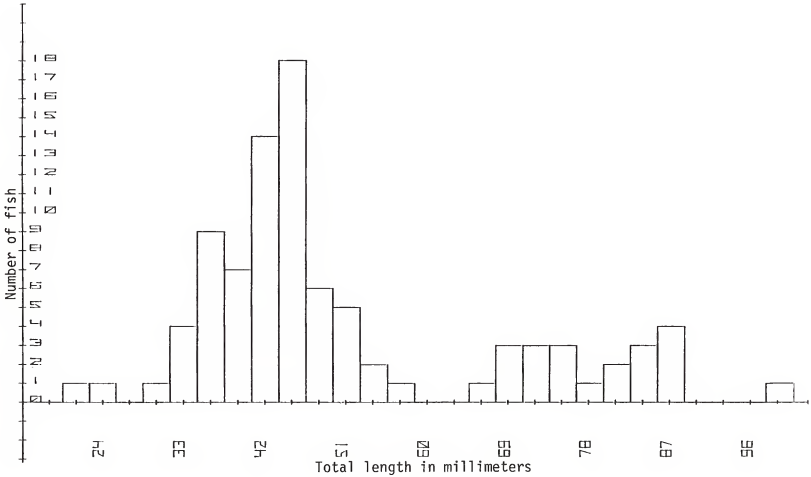


FIGURE 2.38

LENGTH-FREQUENCY DISTRIBUTION OF 90 SPECKLED DACE
COLLECTED JUNE 21-25, 1976

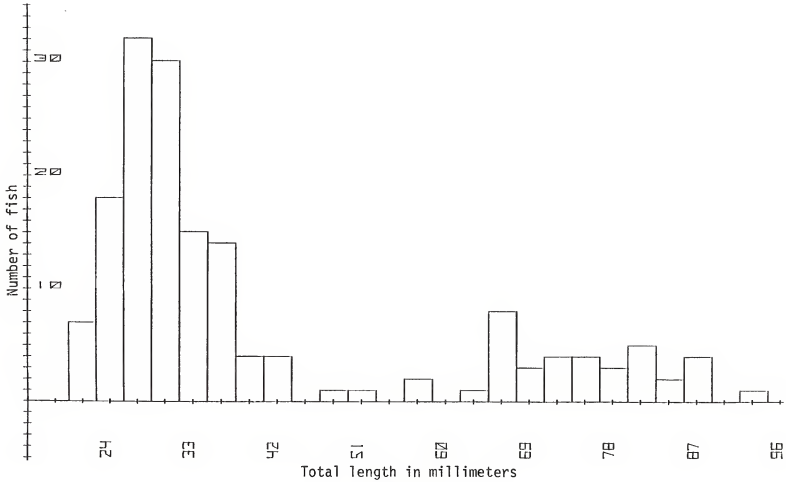


FIGURE 2.39

LENGTH-FREQUENCY DISTRIBUTION OF 163 SPECKLED DACE
COLLECTED AUGUST 2-6, 1976

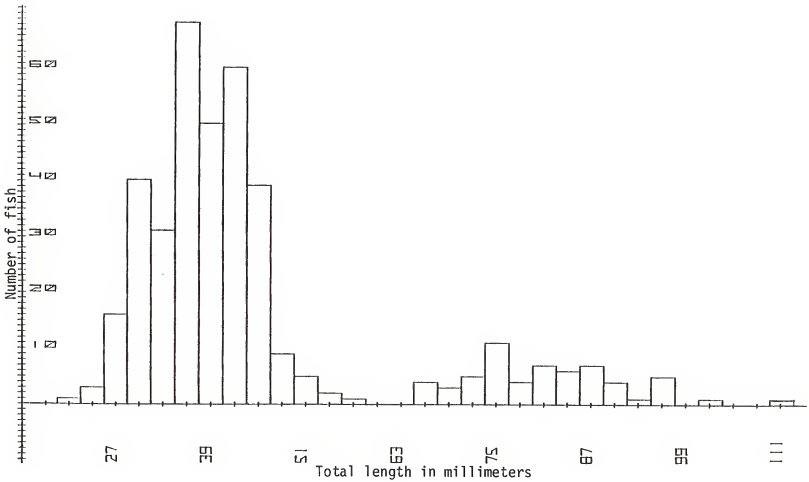


FIGURE 2.40

LENGTH-FREQUENCY DISTRIBUTION OF 381 SPECKLED DACE
COLLECTED AUGUST 30-SEPTEMBER 3, 1976

Condition factors for four White River species taken during the second year of baseline studies are presented in Table 2.67. The data are presented by sampling period and size group as well as by overall means. There are no apparent differences among size groups or sampling periods. The combined means for each species are essentially the same as the corresponding values reported for the previous year as shown below:

	First Year Oct. 1974-Sept. 1975	Second Year Oct. 1975-Sept. 1976
Flannelmouth sucker	0.87	0.84
Bluehead sucker	0.93	0.95
Mottled sculpin	1.42	1.44
Speckled dace	1.04	1.10

E. Food Habits

1. Flannelmouth Sucker

The diet of flannelmouth suckers in the study area during the second year of study primarily consisted of midge larvae (Chironomidae) and mayfly nymphs (Ephemeroptera) (Table 2.68). Caddisfly larvae of the family Hydropsychidae were important diet constituents during August and September 1976. Algae or plant material occurred in only 12 of 79 stomachs that contained food.

The flannelmouth sucker stomach data are similar to those of the previous year (RBOSP Aquatic Studies Annual Report 1976), i.e., Chironomidae and Ephemeroptera dominated the diets. However, in both years, the relative contribution of mayflies was reduced during the summer. In the second year of the study, caddisfly larvae became more important during summer; this change did not take place during the first year. Algae and other plant material were minor constituents of the diet in both years.

TABLE 2.67
CONDITION (K) FACTORS FOR FOUR FISH SPECIES CAPTURED
AT THE RBOSP SITE FROM OCTOBER 1975 THROUGH SEPTEMBER 1976

Length Range (mm)	October 13-17, 1975				November 17-20, 1975				April 12-16, 1976			
	Min.	Max.	X	N	Min.	Max.	X	N	Min.	Max.	X	N
Flannelmouth sucker												
0-60	--	--	--	--	0.76	0.88	0.81	3	--	--	--	--
61-120	0.95	0.98	0.97	3	--	--	--	--	0.35	1.11	0.85	15
121-240	0.94	0.94	0.94	1	--	--	--	--	0.86	0.95	0.90	2
240-320	--	--	--	--	--	--	--	--	0.76	0.97	0.86	11
>320	--	--	--	--	0.78	0.96	0.87	11	0.77	0.98	0.87	26
All groups			0.96	4			0.86	14			0.87	54
Bluehead sucker												
0-200	0.99	1.26	1.12	5	0.94	1.02	0.98	2	--	--	--	--
>201	--	--	--	--	1.05	1.05	1.05	1	1.09	1.10	1.10	3
All groups			1.12	5			1.00	3			1.10	3
Mottled sculpin												
0-50	1.17	1.54	1.31	10	1.26	1.26	1.26	1	--	--	--	--
51-75	0.90	1.51	1.36	19	1.36	1.36	1.36	1	--	--	--	--
>75	1.11	2.00	1.53	67	1.46	2.40	1.70	7	0.22	1.60	1.12	3
All groups			1.47	96			1.61	9			1.12	3
Speckled dace												
0-60	0.70	1.40	1.04	39	0.88	1.18	1.03	18	0.41	6.48	1.12	16
>61	0.84	1.18	1.03	31	1.13	1.13	1.13	1	0.93	1.03	0.98	4
All groups			1.04	70			1.04	19			1.09	20

TABLE 2.67 (Continued)

Length Range (mm)	June 21-25, 1976 Min.	Max.	X	N	August 2-6, 1976 Min.	Max.	X	N	August 30-September 3, 1976 Min.	Max.	X	N	All Sampling Periods X	N
Flannelmouth sucker														
0-60	0.58	1.22	0.91	13	0.32	1.47	0.76	163	0.32	2.01	0.89	68		
61-120	0.73	1.05	0.88	4	--	--	--	--	0.80	1.01	0.90	14		
121-240	0.55	1.01	0.82	10	0.96	1.04	0.99	3	0.73	2.05	1.05	17		
240-320	0.82	1.10	0.93	7	0.30	1.03	0.76	10	0.89	1.12	1.01	2		
>320	0.23	1.21	0.85	15	0.74	1.24	0.88	10	0.98	0.98	0.98	1		
All groups			0.88	49			0.77	186			0.92	102	0.84	405
Bluehead sucker														
0-200	0.90	1.28	1.06	6	0.40	1.03	0.76	34	0.61	1.65	1.00	53		
>201	0.84	0.86	0.85	2	0.90	1.40	1.15	4	1.40	1.40	1.40	1		
All groups			1.01	8			0.80	38			1.01	54	0.95	111
Mottled sculpin														
0-50	--	--	--	--	1.03	1.80	1.31	70	0.98	2.43	1.47	129		
51-75	1.46	1.78	1.59	9	1.42	1.61	1.51	2	0.79	1.85	1.44	28		
>75	1.42	1.71	1.56	11	1.36	1.45	1.45	3	1.05	1.72	1.42	54		
All groups			1.57	20			1.32	75			1.45	211	1.44	414
Speckled dace														
0-60	0.56	1.78	1.01	64	0.42	2.66	1.04	128	0.56	4.21	1.16	326		
>61	0.93	1.28	1.07	21	0.77	1.18	1.02	35	0.90	1.53	1.07	59		
All groups			1.03	85			1.04	163			1.15	385	1.10	742

X = Mean

N = Number of specimens

TABLE 2.68
SUMMARY OF FOOD HABIT ANALYSES FOR FLANNELMOUTH SUCKERS TAKEN
AT THE RBOSP SITE FROM OCTOBER 1975 THROUGH SEPTEMBER 1976

Food Type	Oct. 13-17, 1975 N=4; 107-141mm		Nov. 17-20, 1975 N=9; 408-510mm		Apr. 12-16, 1976 N=55; 91-501mm	
	% frequency of occurrence	% of total food items	% frequency of occurrence	% of total food items	% frequency of occurrence	% of total food items
Nematoda	-	-	22	2	2	<1
Acari	-	-	-	-	15	3
Plecoptera	-	-	22	2	66	3
Ephemeroptera	66	13	89	21	87	24
Trichoptera						
Hydropsychidae	-	-	44	14	70	1
Hydroptilidae	-	-	-	-	15	<1
others	-	-	-	-	2	<1
Lepidoptera	-	-	-	-	13	<1
Diptera						
Chironomidae	100	83	100	54	94	71
Simuliidae	-	-	22	6	4	<1
others	33	4	11	2	11	<1
adult (terrestrial) insects	-	-	22	2	4	<1
algae	-	-	44	-	-	-
plant material	-	-	-	-	2	-
Number of stomachs examined that contained food items	3		9		47	

TABLE 2.68 (Continued)

Food Type	June 21-25, 1976 N=9; 70-471mm % frequency of occurrence	June 21-25, 1976 N=9; 70-471mm % of total food items	Aug. 2-6, 1976 N=18; 26-258mm % frequency of occurrence	Aug. 2-6, 1976 N=18; 26-258mm % of total food items	Aug. 30-Sept. 3, 1976 N=30; 44-398mm % frequency of occurrence	Aug. 30-Sept. 3, 1976 N=30; 44-398mm % of total food items
Nematoda	-	-	25	8	-	-
Acari	-	-	-	-	-	-
Plecoptera	-	-	-	-	18	<1
Ephemeroptera	20	<1	50	10	45	17
Trichoptera						
Hydropsychidae	20	<1	50	18	18	36
Hydroptilidae	20	<1	-	-	-	-
others	-	-	-	-	-	-
Lepidoptera	-	-	-	-	-	-
Diptera						
Chironomidae	100	99	25	61	73	45
Simuliidae	-	-	50	2	-	-
others	-	-	25	1	9	<1
adult (terrestrial) insects	-	-	-	-	-	-
algae	20	-	-	-	18	-
plant material	-	-	-	-	-	-
	-	-	-	-	-	-
Number of stomachs examined that contained food items	5		4		11	

N = Number of specimens

The designation of the flannelmouth sucker as a herbivore in the literature was discussed in RBOSP Aquatic Studies Annual Report (1976). Two additional reports have since been reviewed (Prewitt 1976 and Pratt 1938), and these also reported the flannelmouth sucker as primarily a herbivore. However, the flannelmouth sucker in the RBOSP study area of the White River feeds primarily on immature insects.

2. Mottled Sculpin

The dominant food items of the mottled sculpin during the second year, (October 1975-September 1976) were immature mayflies (Ephemeroptera), caddisflies (Hydropsychidae) and midges (Chironomidae) (Table 2.69). These same organisms dominated in the diet of mottled sculpins taken between October 1974 and September 1975 (See RBOSP Aquatic Studies Annual Report 1976, Table 3-8-231). Seasonal variability was similar in both years for stoneflies and caddisflies. Stonefly nymphs were a significant diet constituent only in April of both years. Caddisfly nymphs were important in October and September of both years. Midge larvae were relatively abundant in the diet in July and September of the first year and were moderately abundant throughout the second year. Occurrence of mayfly nymphs showed a distinctly different pattern in the two years. They were important in October 1974, and April and June 1975, but were low in abundance in July and September 1975. In contrast, immature mayflies were important diet constituents in all samples taken from October 1975 to September 1976.

The diet of the mottled sculpins of the RBOSP White River study area is generally similar to those in literature reports of other populations (Bailey 1952, Ricker 1934, as cited in Scott and Crossman 1973). However, mayfly nymphs constituted a much greater proportion of the diet in the present study than in the Bailey (1952) study on the West Gallatin River, Montana.

TABLE 2.69
SUMMARY OF FOOD HABIT ANALYSES FOR MOTTLED SCULPIN TAKEN AT THE RBOSP SITE
FROM OCTOBER 1975 THROUGH SEPTEMBER 1976

Food Type	Oct. 13-17, 1975 N=94; 44-126mm % frequency of occurrence	Oct. 13-17, 1975 N=94; 44-126mm % of total food items	Apr. 12-16, 1976 N=3; 87-106mm % frequency of occurrence	Apr. 12-16, 1976 N=3; 87-106mm % of total food items
Nematoda	3	<1	-	-
Crustacea	-	-	-	-
Oligochaeta	-	-	-	-
Plecoptera	15	2	66	9
Ephemeroptera	45	27	100	44
Odonata	-	-	-	-
Trichoptera				
Hydropsychidae	87	52	-	-
other	6	<1	-	-
Lepidoptera	9	<1	-	-
Coleoptera	1	<1	-	-
Diptera				
Chironomidae	48	17	66	48
Simuliidae	1	<1	-	-
other	-	-	-	-
Hemiptera				
Corixidae	-	-	-	-
Fish	2	<1	-	-
Number of stomachs examined that contained food items	87		3	

TABLE 2.69 (Continued)

Food Type	June 21-25, 1976 N=20; 65-92mm % frequency of occurrence	June 21-25, 1976 N=20; 65-92mm % of total food items	Aug. 2-6, 1976 N=72; 23-91mm % frequency of occurrence	Aug. 2-6, 1976 N=72; 23-91mm % of total food items	Aug. 30-Sept. 3, 1976 N=211; 34-110mm % frequency of occurrence	Aug. 30-Sept. 3, 1976 N=211; 34-110mm % of total food items
Nematoda	-	-	-	-	<1	<1
Crustacea	-	-	-	-	-	-
Oligochaeta	-	-	-	-	<1	<1
Plecoptera	32	3	-	-	2	<1
Ephemeroptera	89	56	97	82	76	47
Odonata	-	-	-	-	-	-
Trichoptera						
Hydropsychidae	42	8	26	11	65	37
other	-	-	-	-	2	<1
Lepidoptera	5	<1	-	-	6	<1
Coleoptera	-	-	-	-	-	-
Diptera						
Chironomidae	63	31	15	6	39	14
Simuliidae	16	2	4	1	3	<1
other	5	<1	-	-	<1	<1
Hemiptera						
Corixidae	-	-	2	<1	-	-
Fish	-	-	-	-	2	<1
Number of stomachs examined that contained food items	19		66		199	

N = Number of specimens examined

3. Mountain Whitefish

Seventeen mountain whitefish stomachs were examined and were found to contain a variety of immature aquatic insects (Table 2.70). Mayflies (Ephemeroptera), caddisflies of the families Hydropschidae and Hydroptilidae, and midge larvae (Chironomidae) were important food items during at least one of the sampling periods.

During the previous year's study, Hydropsychidae and Chironomidae and, to a lesser extent, Ephemeroptera were important food items (see RBOSP Aquatic Studies Annual Report 1976, Table 3-8-234).

Mountain whitefish are considered primarily bottom feeders (Scott and Crossman 1973); however, Pontius and Parker (1973) and Thompson and Davies (1976) demonstrated that mountain whitefish also feed on drifting organisms. The dominant constituents of the diet of Alberta mountain whitefish in the Sheep River were immature caddisflies, mayflies, and true flies (Dipterans) (Thompson and Davies 1976). Midge and caddisfly larvae were predominant in mountain whitefish stomachs from the Snake River, Wyoming (Pontius and Parker 1973). Chironomid and simuliid larvae (Diptera) dominated the stomach contents of 14 mountain whitefish examined from the Yampa River, just north of the present study area in Colorado (Prewitt 1976). These literature results are generally similar to those reported for the present investigation.

Fishes in the White River RBOSP study area depend on the benthic community for food. The present study and data in the literature indicate that the dominant fishes feed on benthic algae, as in the case of the bluehead sucker (see RBOSP Aquatic Studies Annual Report 1976), or on benthic macroinvertebrates, e.g., flannelmouth suckers and mottled sculpin. There are no obligate plankton feeders because there is no plankton community _per se._ Although several of the species present in the White River feed on other fish occasionally, e.g., mottled sculpin and brown trout, none is primarily piscivorous.

TABLE 2.70
SUMMARY OF FOOD HABIT ANALYSES FOR MOUNTAIN WHITEFISH TAKEN AT THE RBOSP SITE
IN OCTOBER, NOVEMBER, 1975 AND APRIL, 1976

	Oct. 13-17, 1975		Nov. 17-20, 1975		Apr. 12-16, 1976	
	N=8; 120-146mm		N=2; 345-351mm		N=7; 127-227mm	
Food Type	% frequency of occurrence	% of total food items	% frequency of occurrence	% of total food items	% frequency of occurrence	% of total food items
Nematoda	-	-	50	10	-	-
Ephemeroptera	100	42	100	8	100	4
Odonata						
Coenagrionidae	-	-	50	20	-	-
Trichoptera						
Hydropsychidae	100	13	100	23	86	<1
Hydroptilidae	38	10	-	-	1	<1
Diptera						
Chironomidae	100	34	100	35	86	95
Simuliidae	12	1	50	2	14	<1
Plecoptera						
Isoperla	-	-	50	2	29	<1
Lepidoptera						
Pyralidae	-	-	50	<1	14	<1
Terrestrial insects	12	1	-	-	-	-
Number of stomachs examined that contained food items	8		2		7	

N = Number of specimens examined

F. Reproduction

The data from the period October 1975-September 1976 corroborate the previous years' finding that flannelmouth suckers attain sexual maturity when they are about 400 mm in total length. During April 1976, the 13 mature female flannelmouth suckers that were captured ranged from 403-501 mm in total length. One additional, readily recognizable but immature female was captured that measured 376 mm. Only one mature male (400 mm) was captured.

It is difficult to assign "age at maturity" to the flannelmouth suckers because of the tentative nature of the flannelmouth sucker scale analyses, as previously discussed. However, the 400 mm length at maturity mentioned above consistently falls within the length ranges of fish aged at about six years old in June and July (see Table 2.65).

Because of the presence of ripe (sexually mature, ready to spawn) flannelmouth suckers in April and largely spent fish in June of the 1975 spawning season (see RBOSP Aquatic Studies Annual Report 1976), it was surmised that spawning had probably taken place largely in June at water temperatures of 12-13 C. The same events took place during 1976, but there is some evidence that spawning took place earlier, or at least that egg incubation was much more rapid.

In late June and July 1975, no flannelmouth suckers smaller than 45 mm were collected. Young-of-year were first collected in September of 1975. Although fishes of this size are incompletely sampled by the gear used, their absence from the late June and July collections suggests that they were late in hatching. In contrast, in late June of 1976, 13 specimens averaging 17 mm total length were captured. Also, in late August-early September, the apparent young-of-year group was considerably larger in 1976 (Figure 2.31) than in 1975 (Figure 2.29). These facts suggest that spawning took place much earlier in 1976 than in the previous year.

The earlier spawning period was probably induced by more rapidly rising water temperatures as a result of a shorter snow melt runoff period in 1976 compared

to 1975. In 1975, water temperatures were uniformly 12-13 C in both late April and late June. In late April 1976, White River water temperatures ranged from 7-11 C. However in June 1976, temperatures were 14-18 C, as opposed to 12-13 during June 1975. Consequently, spawning and egg hatching occurred earlier.

Fecundity, or estimates of the total number of eggs contained in the ovaries, was estimated for two flannelmouth suckers captured in April 1975 and for 13 fish captured in April 1976. The estimates ranged from 7,276 to 13,841 eggs and appeared to be linearly correlated with the total length of the fish (Figure 2.41). This gives some idea of the spawn production potential of the flannelmouth sucker, but it is an overestimate because not all eggs in the ovaries are spawned in a given year. No data on flannelmouth sucker fecundity is available in the literature for comparison.

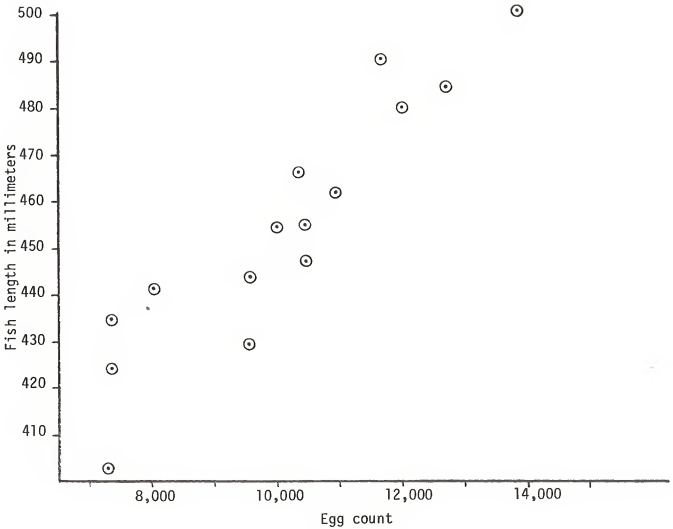


FIGURE 2.41

LENGTH-FECUNDITY RELATIONSHIP OF 15 FLANNELMOUTH SUCKERS
CAPTURED AT THE RBOSP SITE DURING APRIL, 1975 AND 1976

VII. RELATIONSHIPS OF HABITAT, SEASON, AND BIOTIC COMPONENTS

A general analysis of variance was performed to determine the significance of the observed differences among habitats, based on total numbers of benthos and periphyton. The results (Tables 2.71 to 2.74, indicate that, although the habitat classification had been developed from biotic and physical data, habitats were usually significantly different from each other and thus appear to represent valid categories.

Habitat differences based on total numbers of periphytic organisms (Table 2.74) indicate that with the exception of habitats 1 (Ponds) versus 3 (Yellow Creek) and 4 versus (White River back channel) versus 5 (White River open channel), the numbers of organisms were very significantly different among the habitats. Habitats 1 and 3 might be expected to have similar organism densities; the ponds have high nutrient content and due to the slower flow develop higher standing crops than the spring brooks, and Yellow Creek often developed higher standing crops than the spring brooks due to its size and greater source of seed material. The White River habitats consistently averaged higher standing crops than other habitats, due to the more favorable chemical climate and greater seed availability. The back channel and main channel (habitats 4 and 5) were very similar in densities, due to the similar flow velocities and same water source.

Habitat differences based on total numbers of benthic invertebrates (Table2.72) were even more striking; all habitats were significantly or very significantly different from each other. Predictably, the habitats with the least (but still significant) differences were 2 versus 3, and 4 versus 5.

Analyses of variance were also performed to determine if there were differences in total numbers of periphytic organisms or benthic invertebrates between the years sampled (Tables 2.71 - 2.73). In both cases there were no significant differences between years, indicating that at least in terms of organism densities both baseline years were similar. This indicates that the baseline data should be typical for the area and that no outstanding or unusual environmental events occurred in either year sampled.

TABLE 2.71

ANALYSIS OF VARIANCE AMONG HABITATS BASED ON
TOTAL NUMBERS OF BENTHOS
(least squares method)

	SOURCE	D.F.	S.S.	M.S.
1	YEAR	1.	10.7869040539	10.7869040539
2	DATE(YEAR)	10.	114.1906142942	11.4190614294
3	HABITAT	4.	90.8439764277	22.7109941069
4	SITE(HABITAT)	27.	44.8873005596	1.6624926133
5	YEAR*HABITAT	4.	32.6649512668	8.1662378167
6	ERROR	916.	228.9728851318	0.2499703986
7	MEAN	1.	10778.7539062500	
8	TOTAL	963.	11327.3173179030	

CORRECTED S.S. 548.56323242

EXPLAINED S.S. 319.59033203

R-SQUARED = 0.5826 R = 0.7633

TABLE 2.72

RESULTS OF ANALYSIS OF VARIANCE OF BENTHOS
AMONG YEARS AND HABITATS
(least squares method)

Main Effects - Season

	LS EFFECT	S.E.	LS MEAN	S.E. OF MEAN
1	-0.122681	0.018676	3.277286	0.028138
2	0.122681	0.018676	3.522648	0.025236

MEAN 1 - MEAN 2	DIFFERENCE	S.E. OF DIFF.(DUNCAN)	S.E. OF DIFF.
1 2	-0.245362	0.026411	0.037351

Main Effects - Habitat

	LS EFFECT	S.E.	LS MEAN	S.E. OF MEAN
1	0.745634	0.042500	4.145600	0.049397
2	-0.063731	0.032868	3.336236	0.035126
3	-0.079334	0.043371	3.320633	0.050976
4	-0.306888	0.035489	3.093080	0.039388
5	-0.295682	0.030262	3.104285	0.030768

MEAN 1 - MEAN 2	DIFFERENCE	S.E. OF DIFF.(DUNCAN)	S.E. OF DIFF.
1 2	0.809365	0.042708	0.060399
1 3	0.824968	0.049977	0.070678
1 4	1.052521	0.044489	0.062916
1 5	1.041315	0.041063	0.058071
2 3	0.015603	0.043445	0.061441
2 4	0.243157	0.037059	0.052409
2 5	0.231951	0.032974	0.046633
3 4	0.227554	0.045106	0.063790
3 5	0.216348	0.041886	0.059235
4 5	-0.011206	0.035115	0.049660

TABLE 2.73

ANALYSIS OF VARIANCE AMONG HABITATS BASED
ON TOTAL NUMBERS OF PERIPHYTON
(least squares method)

	SOURCE	D.F.	S.S.	M.S.
1	YEAR	1.	0.6552777901	0.6552777901
2	DATE (YEAR)	10.	46.9454704915	4.6945470491
3	HABITAT	4.	104.3923433919	26.0980858480
4	SITE (HABITAT)	27.	43.7371729508	1.6198952945
5	YEAR*HABITAT	4.	2.3055827622	0.5763956905
6	ERROR	923.	244.1307678223	0.2644970399
7	MEAN	1.	12791.7226562500	
8	TOTAL	970.	13259.4421157837	

CORRECTED S.S. 467.71923828
EXPLAINED S.S. 223.58847046
R-SQUARED = 0.4780 R = 0.6914

TABLE 2.74

RESULTS OF ANALYSIS OF VARIANCE OF PERIPHYTON
AMONG YEARS AND HABITATS
(least squares method)

Main Effects - Year

	LS EFFECT	S.E.	LS MEAN	S.E. OF MEAN
1	-0.029672	0.018852	3.601828	0.027371
2	0.029672	0.018852	3.661172	0.026753

MEAN 1 - MEAN 2		DIFFERENCE	S.E. OF DIFF.(DUNCAN)	S.E. OF DIFF.
1	2	-0.059344	0.026660	0.037703

Main Effects - Habitat

	LS EFFECT	S.E.	LS MEAN	S.E. OF MEAN
1	-0.051865	0.044895	3.579635	0.052412
2	-0.524865	0.034879	3.106635	0.037670
3	-0.108014	0.044753	3.523486	0.052251
4	0.320190	0.035726	3.951690	0.038700
5	0.364553	0.030851	3.996053	0.030895

MEAN 1 - MEAN 2		DIFFERENCE	S.E. OF DIFF.(DUNCAN)	S.E. OF DIFF.
1	2	0.473000	0.045454	0.064282
1	3	0.056149	0.052233	0.073868
1	4	-0.372055	0.046080	0.065167
1	5	-0.416418	0.043044	0.060873
2	3	-0.416851	0.045322	0.064095
2	4	-0.845054	0.038222	0.054055
2	5	-0.889418	0.034522	0.048821
3	4	-0.428203	0.045978	0.065022
3	5	-0.472567	0.042923	0.060702
4	5	-0.044363	0.034988	0.049480

A statistical power study was undertaken to assess what changes in the minimum detectable difference among means would occur by collecting three replicates as in the aquatic baseline program. The method employed for the assessment was to compute a general analysis of variance table for benthos and periphyton (Table 2.75 - 2.76). The coefficients in the expected mean squares were included in the table and employed in conjunction with the power charts of Pearson and Hartley (1972) to demonstrate the change in power. A 0.05 level of significance was assumed for all calculations. The parameters employed were logarithmically transformed prior to the statistical analyses (i.e., y - log 10 (x+1)).

Table 2.75 is the general analysis of variance table for benthos and periphyton, respectively. The coefficients in the expected mean squares were calculated using a method by H. O. Hartley (1967). These coefficients along with Eq 163 of Pearson and Hartley (1972) were used to calculate the minimum detectable difference for the Year * Habitat and Habitat factors. Table 2.76, illustrates the use of Eq 173 of Pearson and Hartley (1972) in arriving at a general expression for the minimum detectable difference.

Tables 2.77 - 2.78 identifies the parameters used in the statistical assessment along with the maximum difference observed. Estimates of the detectable difference for each parameter were calculated under a specification of 80 percent power for three and two replicates. The power of a statistical test is the ability of the test to detect a difference that truly exists. An 80 percent power means that the test will detect a true difference 80 percent of the time. As seen in Tables 2.77 and 2.78 the baseline sampling has provided statistically powerful results.

For the Year * Habitat and Habitat factors, the observed maximum difference is greater than the minimum detectable difference for three and two replicates for the benthos and periphyton parameter studies.

TAB[illegible].75

ANALYSIS OF VARIANCE FOR BENTHOS AND PERIPHYTON COLLECTED FROM WHITE RIVER OPEN CHANNEL HABITATS

Benthos

Source of Variation	Three Replicates: Degrees of Freedom	Three Replicates: Expected Mean Squares	Two Replicates: Degrees of Freedom	Two Replicates: Expected Mean Squares
Year	1	$\sigma_e^2 + 59.7\ \sigma^2_{D(Y)} + 358.3\kappa^2_Y$	1	$\sigma_e^2 + 39.7\ r^2_{D(Y)} + 238.0\kappa^2_Y$
Date (Year)	10	$\sigma_e^2 + 78.5\ \sigma^2_{D(Y)}$	10	$\sigma_e^2 + 52.5\ r^2_{D(Y)}$
Habitat	4	$\sigma_e^2 + 160.7\ \kappa^2_H$	4	$\sigma_e^2 + 107.5\ \kappa^2_H$
Sites (Habitat)	27	$\sigma_e^2 + 29.4\ \kappa^2_{S(H)}$	27	$\sigma_e^2 + 19.7\ \kappa^2_{S(H)}$
Year * Habitat	4	$\sigma_e^2 + 89.3\ \kappa^2_{YH}$	4	$\sigma_e^2 + 59.7\ \kappa^2_{YH}$
Remainder	916	σ_e^2	597	σ_e^2
Total	962		643	

Periphyton

Source of Variation	Three Replicates: Degrees of Freedom	Three Replicates: Expected Mean Squares	Two Replicates: Degrees of Freedom	Two Replicates: Expected Mean Squares
Year	1	$\sigma_e^2 + 62.0\ r^2_{D(Y)} + 372.1\ \kappa^2_r$	1	$\sigma_e^2 + 41.7\ r^2_{D(Y)} + 250\ \kappa^2_Y$
Date (Year)	10	$\sigma_e^2 + 79.2\ r^2_{D(Y)}$	10	$\sigma_e^2 + 52.9\ r^2_{D(Y)}$
Habitat	4	$\sigma_e^2 + 159.9\ \kappa^2_H$	4	$\sigma_e^2 + 107.3\ \kappa^2_H$
Sites (Habitat)	27	$\sigma_e^2 + 29.6\ \kappa^2_{S(H)}$	27	$\sigma_e^2 + 19.8\ \kappa^2_{S(H)}$
Year * Habitat	4	$\sigma_e^2 + 90.3\ \kappa^2_{YH}$	4	$\sigma_e^2 + 60.4\ \kappa^2_{SH}$
Remainder	923	σ_e^2	601	σ_e^2
Total	969		647	

LEGEND:

Year	DATE
1	10/74, 12/74, 4/75, 6/75, 7/75, 8/75
2	10/75, 11/74, 4/76, 6/76, 7/76, 8/76

Habitat	Site
1 (Pond)	5,14,19
2 (Spring Brook)	1,2,3,4,6,7,8,9,12,13,15,17,18
3 (Yellow Creek)	20,21,22
4 (Back Channel)	23,27,28,29,33
5 (Open Channel)	24,25,26,30,31,32,34,35

TABLE 2.76

ILLUSTRATION OF USE OF PEARSON AND HARTLEY \ EQ 173 TP ARRIVE AT MINIMUM DETECTABLE DIFFERENCE

Benthos

Year & Habitat
Three Replicates

$$W = \sqrt{5/89.3}\ \phi\ \sigma_e\ \sqrt{10/11} = 0.1504\ \phi\ \sigma_e$$

Two Replicates

$$W = \sqrt{5/59.7}\ \phi\ \sigma_e\ 2\sqrt{10/99} + 0.1840\ \phi\ \sigma_e$$

Habitat
Three Replicates

$$W = \sqrt{5/160.7}\ \phi\ \sigma_e\ 2\ \sqrt{5/24} = 0.1601\ \phi\ \sigma_e$$

$$W = \sqrt{5/107.5}\ \phi\ \sigma_e\ 2\sqrt{5/24} = 0.1969\ \phi\ \sigma_e$$

Periphyton

Year & Habitat
Three Replicates

$$W = \sqrt{5/90.3}\ \phi\ \sigma_e\ 2\sqrt{10/99} = 0.1496\ \phi\ \sigma_e$$

Two Replicates

$$W = \sqrt{5/60.4}\ \phi\ \sigma_e\ 2\sqrt{10/99} = 0.1829\ \phi\ \sigma_e$$

Habitat
Three Replicates

$$W = \sqrt{5/159.7}\ \phi\ \sigma_e\ 2\sqrt{5/24} = 0.1615\ \phi\ \sigma_e$$

Two Replicates

$$W = \sqrt{5/107.3}\ \phi\ \sigma_e\ 2\sqrt{5/24} = 0.1971\ \phi\ \sigma_e$$

LEGEND:

W = minimum detectable difference
σ_e = Standard deviation of error mean square
ϕ = non-centrality parameter

TABLE 2.77

PARAMETERS USED AND RESULTS OF STATISTICAL ASSESSMENT OF MAXIMUM DIFFERENCE AMONG BENTHOS SAMPLES

Parameters	σe	Year * Habitat Max. Difference	Min Detectable Difference (80%= 1-β) Three Replicates	Two Replicates
Oligochaeta	0.8606	0.3910	0.2000	0.2447
Insecta	0.5109	0.5342	0.1187	0.1452
Ephemeroptera	0.825	0.7012	0.1865	0.2281
Plecoptera	0.7431	0.5416	0.1727	0.2112
Trichoptera	0.7140	0.3910	0.1659	0.2030
Diptera	0.5481	0.4776	0.1274	0.1558
Chironomidae	0.6092	0.5110	0.1416	0.1732
Miscellaneous	0.2810	0.2400	0.0653	0.0799
Total	0.5000	0.4826	0.1162	0.1421

Parameters	σe	Habitat Max. Difference	Min. Detectable Difference (80%=1-β) Three Replicates	Two Replicates
Oligochaeta	0.8606	1.3512	0.2129	0.2618
Insecta	0.5109	1.0193	0.1264	0.1554
Ephemeroptera	0.8025	1.9287	0.1985	0.2441
Plecoptera	0.7431	1.0402	0.1838	0.2261
Trichoptera	0.7140	1.8112	0.1766	0.2172
Diptera	0.5481	1.4985	0.1356	0.1667
Chironomidae	0.6092	1.3361	0.1507	0.1853
Miscellaneous	0.2810	0.1371	0.0695	0.0855
Total	0.5000	1.0525	0.1237	0.1521

TABLE 2.78

PARAMETERS USED AND RESULTS OF STATISTICAL ASSESSMENT OF MAXIMUM DIFFERENCE AMONG PERIPHYTON SAMPLES

Parameter	σe	Year * Habitat Max. Difference	Min. Detectable Difference (80%= 1-β) Three Replicates	Two Replicates
Cyanophyta	0.9277	0.2720	0.2144	0.2621
Chlorophyta	0.6268	0.3948	0.1449	0.1771
Chrysophyta	0.5173	0.1620	0.1196	0.1462
Cryptophyta	0.0477	0.0150	0.0110	0.0135
Total	0.5143	0.1564	0.1189	0.1453

Parameter	σe	Habitat Max. Difference	Min. Detectable Difference (80%=1-β) Three Replicates	Two Replicates
Cyanophyta	0.9277	2.006	0.2315	0.2825
Chlorophyta	0.6268	0.4922	0.1564	0.1909
Chrysophyta	0.5173	0.8284	0.1291	0.1575
Cryptophyta	0.0477	0.0094	0.0119	0.0145
Total	0.5143	0.8894	0.1283	0.1566

CHAPTER 5 - GROUNDWATER HYDROLOGY

ABSTRACT

Deep aquifer hydrologic information was collected during core hole drilling, formal pumping tests, and the monitoring program. The deep aquifer hydrological monitoring program included measurement of water levels. Water levels in the aquifers were dynamic throughout the baseline period. Aquifer static water levels (SWL) have been approaching equilibrium since the aquifers were isolated after a period of connection through open holes. Water levels in both aquifers appear to fluctuate seasonally. This fluctuation is more pronounced in the upper aquifer than in the lower aquifer. In the saturated alluvium, water level and temperature respond to respective stream flows, which show seasonal variation. The lower aquifer has considerably greater transmissivity than the upper aquifer. Water movement in the upper aquifer may be limited by fault structures. Water movement in both aquifers has a preferred direction from north-northwest. A monitoring and data collection program was initiated to delineate baseline aquifer physical characteristics, to satisfy Tract C-a lease stipulations, and to provide hydrologic information pertinent to Tract C-a development. This chapter contains analysis of data that has been collected by RBOSP from July 1974 through February 1977.

HYDROLOGY

Alluvial, perched, and deep bedrock aquifers are present in the Piceance Creek basin. The only major aquifers found in the vicinity of Tract C-a were the alluvial and deep bedrock aquifers.

The drilling programs indicated two major bedrock aquifer systems are present under Tract C-a as shown on Figure 2.42 and 2.43. The upper aquifer system occurs in the vicinity of the Mahogany zone. The lower aquifer system is associated with the R-3 zone and in some cases is as deep as the Blue marker.

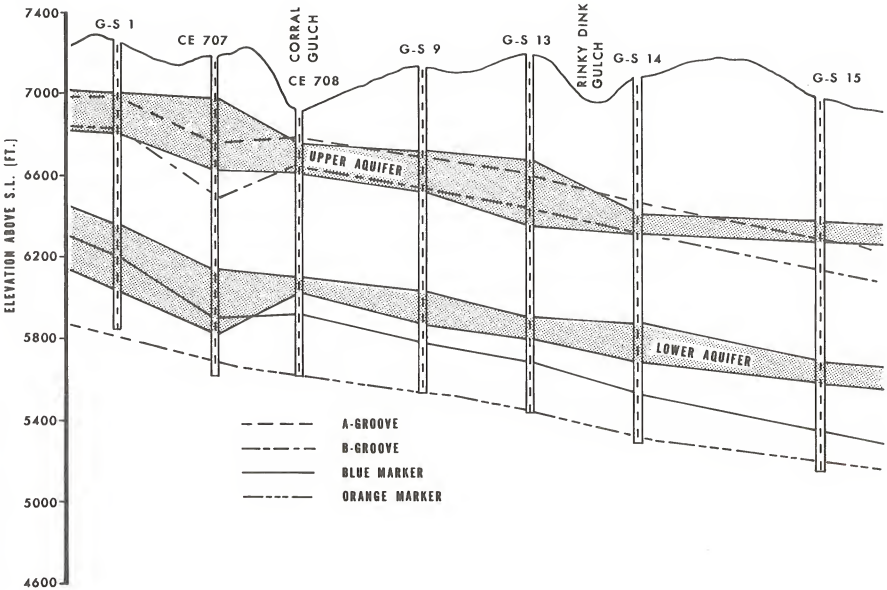


FIGURE 2.42
UPPER AND LOWER BEDROCK AQUIFERS UNDER TRACT C-a

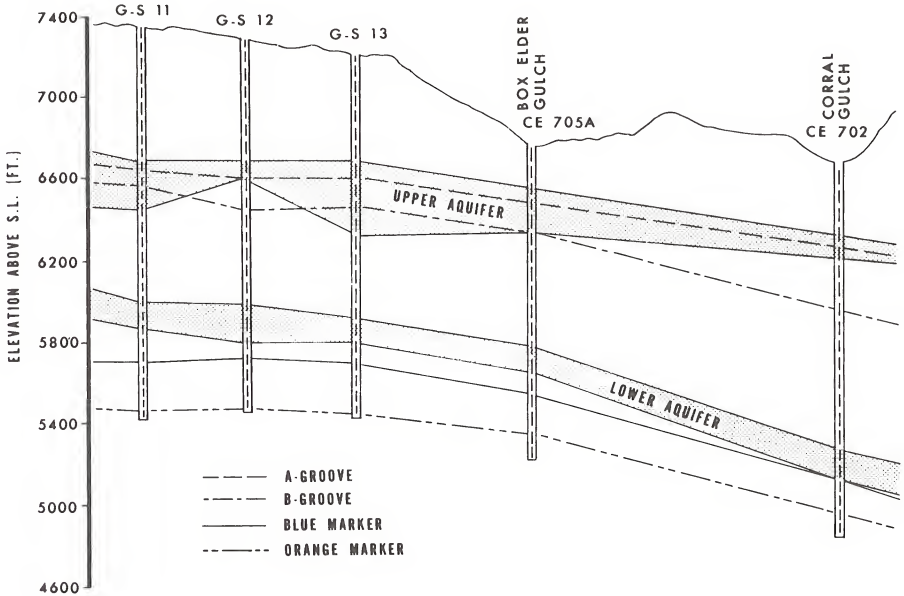


FIGURE 2.43
CROSS SECTION, UPPER AND LOWER BEDROCK AQUIFER

Both aquifer systems are artesian. With the exception of the northeast corner of Tract C-a, the upper aquifer system has a higher potentiometric level than the lower aquifer system. On the average, the difference between the potentiometric levels is approximately 150 feet. Although quite variable from place-to-place, the aquifers each have an average thickness of about 220 feet.

There appears to be a connection between the upper and lower aquifers in the northeast corner of the tract in the area of CE 702, G-S 6, and TO 3, indicated by the drawdown and recovery of the upper aquifer during the lower aquifer pumping tests of G-S D19 and G-S D18 simultaneously.

This interconnection may be the result of faults in the area, inadequate isolation of the two aquifers in one of the three holes located in the northeast corner of the tract, and/or possible man-made fracturing as a result of experimental fracturing work done by WRD-USGS in 1973.

Several categories of hydrologic data were collected during the drilling and coring of the various holes on and around Tract C-a. These included water production, water quality, informal pump test data, and production logging information. The method and intervals at which these data were collected were based upon the AOSS stipulations and approvals of the drilling program and general knowledge from previous area investigations.

With the exception of G-S 4-5 and some prelease holes, the water flow in the bore hole after drilling was from the upper aquifer to the lower aquifer.

The long-term pumping tests made possible the claculation of transmissivity and coefficients of storage at various monitoring holes located on and around the tract. The interpretation of these values resulted in apparent transmissivities of 2,500 gpd/ft and 7,000 gpd/ft for the upper and lower aquifers, respectively. It should be noted that the upper aquifer system responded only locally to stresses created during pumping while the lower aquifer system responded over a large area from single pumping tests. Therefore, the transmissivity and coefficients of storage for the lower aquifer system are considered to be much more representative than those for the upper aquifer system.

The above transmissivities are generally lower than the average values derived from the drilling and pumping test programs. The upper aquifer average values varied from 2,200 gpd/ft to 15,316 gpd/ft. The value of 2,500 gpd/ft is based on the small area affected by pumping the upper aquifer, indicating lower transmissivities than those measured at the pumped hole. In addition, the faults appear to act as barriers to flow in the upper aquifer. The lower aquifer transmissivities were also variable. They ranged from 9,600 gpd/ft to 17,000 gpd/ft.

The value of 9,600 was replaced because the pumping tests evaluation indicated lower values than those actually calculated. Thus, the average of 9,600 gpd/ft was reduced to 7,000 gpd/ft. It should be noted that the lower aquifer pumping tests did not show any evidence of fault influence at that depth suggesting that they die-out with depth.

Calculations were made to determine the leakance value between aquifers. With the exception of the CE 705-A upper aquifer pumping test, values for leakance could not be derived. At this location two permeability values were derived. A value of 75 gpd/sq ft was derived for the permeability between the upper and lower aquifer systems. This may have been due to unobserved leakance between the alluvial aquifer and the upper aquifer system. A value of 25 gpd/sq ft was derived. It is surmised that leakance occurred during all of the pumping tests but that the background water level due to the interconnection of the two aquifers prior to the pumping tests prevents a reasonable determination of the leakance value.

An analysis of the various pumping tests in both aquifer systems revealed an elongation of the cone of depression along the NNW-SSE axis. A comparison of the trends of the major fracture-joints sets on Tract C-a indicates three major directions. These are generally oriented NW-SE, NE-SW, and N-S. The directions are given in order of decreasing number of fracture and joint orientations. Therefore, a resultant preferred directional flow in these aquifers would be along the NNW-SSE as observed during the pumping tests and shown on Figures 2.44 and 2.45.

As indicated by the results of the pumping tests conducted in G-S 12, it appears that some of the faults act as barriers to water movement in the upper aquifer systems as shown in Figure 2.46. It appears highly possible that the upper

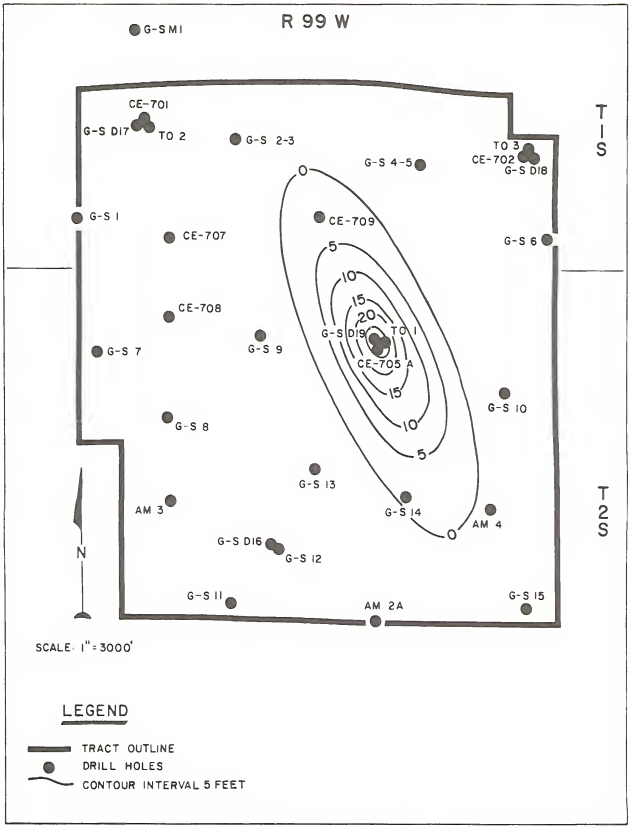


FIGURE 2.44
UPPER AQUIFER PUMPING TEST CONE OF DEPRESSION

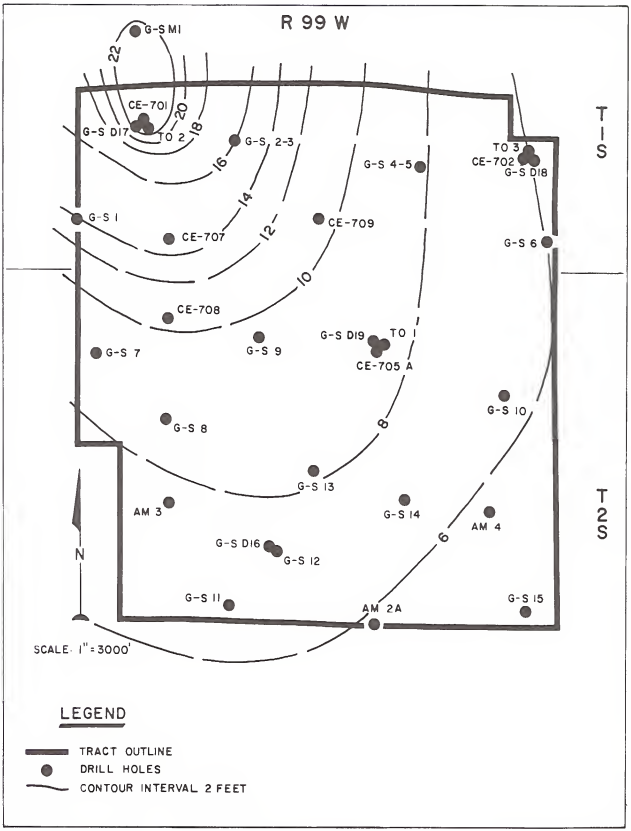


FIGURE 2.45
LOWER AQUIFER PUMPING TEST CONE OF DEPRESSION

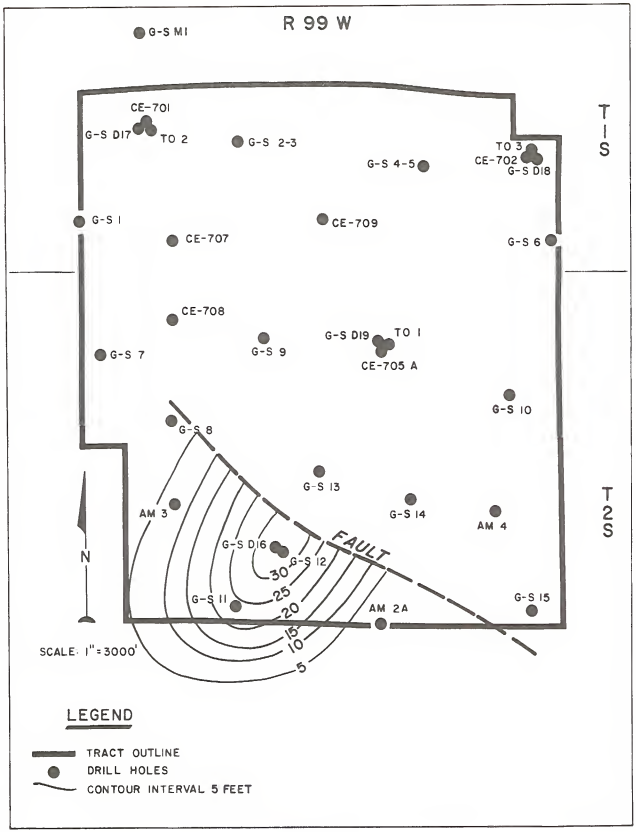


FIGURE 2.46
UPPER AQUIFER PUMPING TEXT DRAWDOWN, G-S 12
AT APPROXIMATELY 13,000 MINUTES

aquifer system may respond to dewatering in a manner similar to an aquifer which has been divided into cells that are only partially connected hydrologically.

I. ALLUVIAL AQUIFERS

Alluvium occurrences were mapped from aerial photographs in the vicinity of Tract C-a. In order to determine the depth, thickness, and water saturation of the alluvium, an alluvial test drilling program was initiated in April 1975. The holes which contain water are being used as monitor holes.

A total of seven alluvial aquifer monitor holes, as shown on Figure 2.47 has been completed, all drilled to bedrock. Of these seven, no water was encountered in three and they have remained dry throughout the monitoring period. The remaining four have had measurable water levels since the initial construction.

Table 2.79 is a summary of data of the alluvial monitor holes on Tract C-a and along Corral Gulch which contained alluvial water. Water levels, pH, temperature, and conductivity were measured in the field each month.

The majority of the alluvial monitor holes which contained water showed water level rises through the months of March to June. The magnitude of the rise varied depending upon the drainage system in which the hole was located. During the remaining summer, fall, and winter months, water levels generally declined as shown in Figure 2.48.

The results of the alluvial monitoring program indicate that the major drainage systems have water saturated alluvium, and that, in many of the minor drainage systems the alluvium is dry. In the major drainage systems the data indicate a seasonal trend in the water levels. This trend shows rising water levels during the snowmelt runoff period and declining water levels the remainder of the year. The limited observations to date from the continuous water level records indicate that the alluvial aquifers respond only indirectly to regional and local precipitation events.

During the pumping tests conducted in the deep oil shale aquifers no measurable hydrologic connection was noted between the alluvial aquifers and the deep oil shale aquifers.

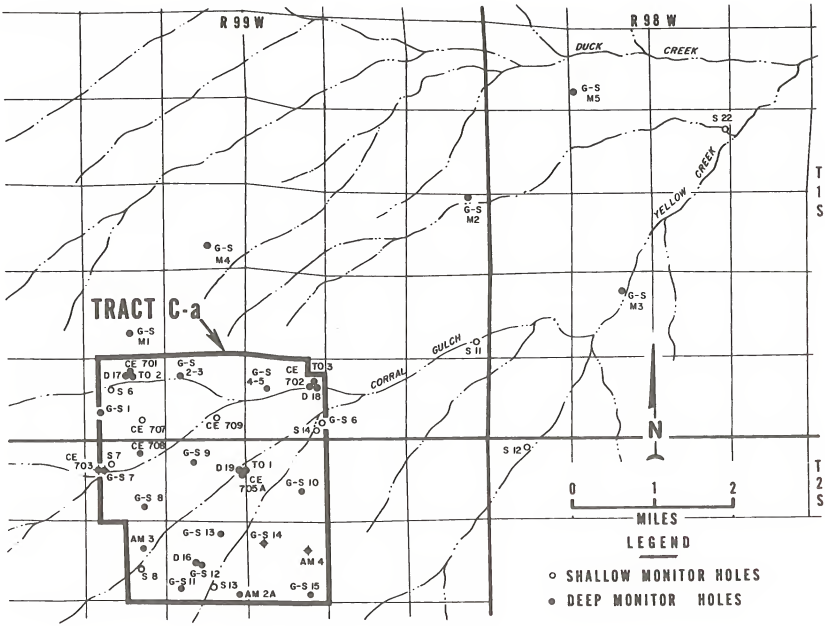


FIGURE 2.47
TRACT C-a MONITORING HOLES

TABLE 2.79

SUMMARY OF ALLUVIAL MONITORING HOLES

PHYSICAL DATA

Hole	Depth (feet)	Mean Static Water Level (feet)	Standard Deviation	Mean Temperature (°F)	Standard Deviation	Mean Conductivity (umhos)	Standard* Deviation
G-S S-7	44	21.6*	2.5	48.6	2.9	1096	58.0
G-S S-8	50	35.7*	3.7	49.2	2.9	970	83.3
G-S S-11	66	44.0	1.5	50.6	3.0	1796	187.5
G-S S-12	87	32.6	1.5	49.7	5.3	1596	135.9

* Geometric mean, standard deviation by method of movements.

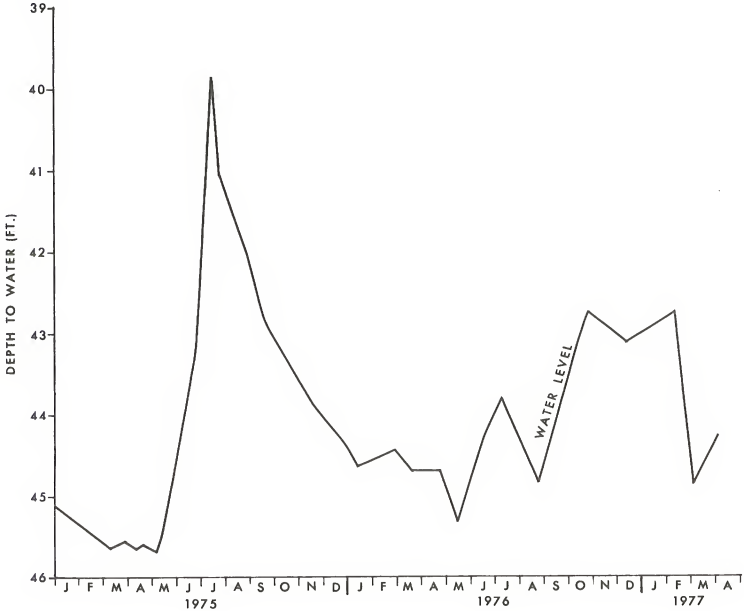


FIGURE 2.48
ALLUVIAL AQUIFER HYDROGRAPH, G-S S11

A histogram of 1976 water level data (Figure 2.49), shows that G-S S-7 and G-S S-8 had low levels of saturation throughout most of the year. This implies that a stable water source was not available to these reaches and that recharge was very short and seasonal in nature. G-S S-11 and G-S S-12 most frequently had water levels that were near their water year average. Therefore, a substantial amount of recharge to these aquifers is from springs, but the seasonal snowmelt still affects these alluvium to a large degree.

A water level correlation matrix helps to show the time relationship of the relative changes in water level in the different alluviums, Figure 2.50. The matrices show that G-S S-7 and G-S S-11 are most associated, which would be expected since they are on the same drainage. G-S S-8 and G-S S-11 are also closely associated since G-S S-8 is in a major tributary to G-S S-11. Since groundwater flow is not a major contribution to saturation of the alluvium at G-S S-8, the correlation between G-S S-8 and G-S S-11 is due to increased recharge from snowmelt and streamflow during similar periods. Also, discharge of water from the alluvium is not substantially different. A slight correlation exists between G-S S-12 and G-S S-11. It is suspected that the spring snowmelt is the main reason for the correlation between these stations.

The time correlation between G-S S-7 and G-S S-8 is inverse and is attributed to differences in exposure and orientation of the drainage. If the two alluvia are correlated without regard to time, a correlation of more than 0.70 is possible. This shows that the nature of the response and discharge due to snowmelt is very similar without respect to time.

A comparison of the water level recession curves in the alluvial aquifers at G-S S-7, S-8, and S-11 indicates that during years in which the water temperature transition from winter to spring is rapid, less recession similarity exists between these aquifers and the rate of recession is less than in years that have early freeze and thaw periods. Early freeze/thaw periods may allow a greater amount of percolation of snowmelt which may smooth out the effects that can be caused by local topography during periods of rapid runoff. This is particularly true for an alluvium that is nearly dry prior to recharge, such as at G-S S-7 during 1976.

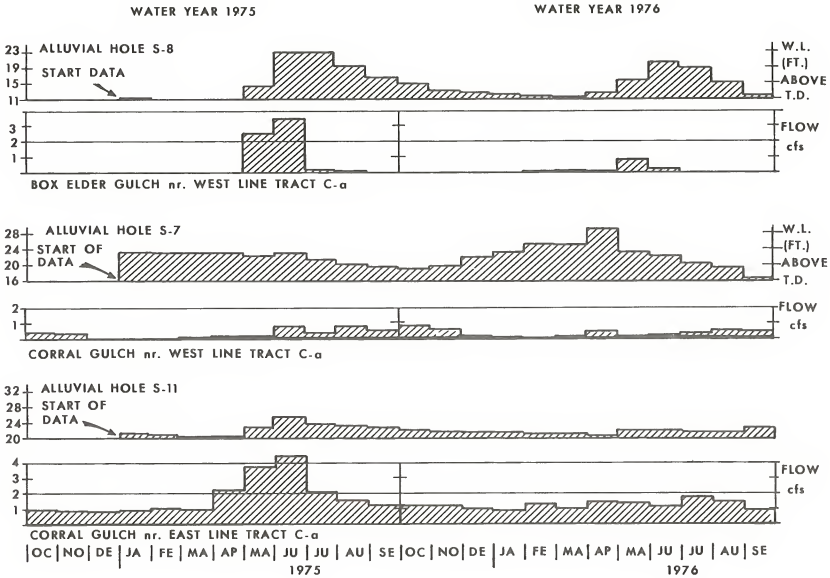
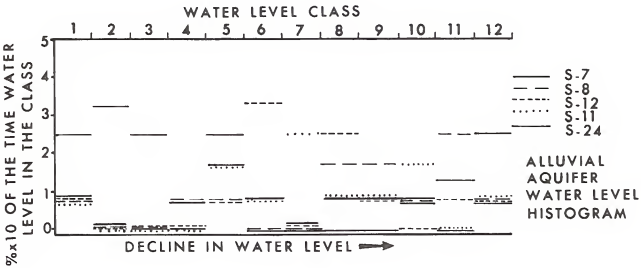


FIGURE 2.49

ALLUVIAL HOLE WATER LEVEL VS. STREAM FLOW



WATER LEVEL (1976)

	S7	S8	S11	S12	S24
S7		-.26	-.72	.01	-.02
S8			.26	.26	.18
S11				.06	.11
S12					
S24					

CONDUCTIVITY (1976)

	S7	S8	S11	S12	S24
S7		.55	.82	.25	.23
S8			.61	.48	.59
S11				.09	.15
S12					.71
S24					

WATER LEVEL (1975)

	S7	S8	S11	S12
S7		.04	.02	.81
S8			.84	.12
S11				.13
S12				

ALLUVIAL AQUIFER CORRELATION (r) MATRIXES

FIGURE 2.50

ALLUVIAL AQUIFER WATER LEVEL HISTOGRAM AND CORRELATION MATRICES

Temperature of alluvial water during the year follows similar patterns from hole to hole over the vicinity of the tract. During periods of highest temperature of the alluvial water, pH often reaches a peak shortly after the peak temperature. This period generally corresponds to minimum saturation of the alluvium.

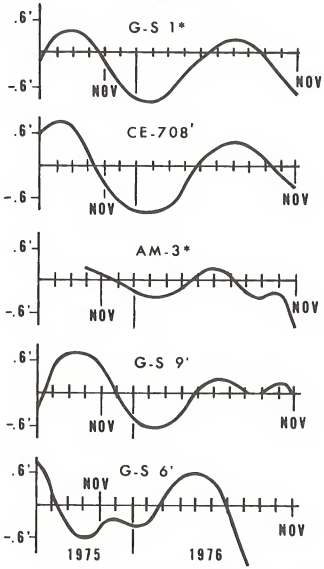
II. UPPER AQUIFER

The upper aquifer includes water-bearing zones of similar water quality and temperature characteristics and has an upper stratigraphic limit above the Mahogany zone and a lower limit as low as the top of the R-5 zone. During the drilling program, production from the upper aquifer varied from as little as 40 gallons per minute (gpm) to over 1,000 gpm, with an average maximum of 247 gpm. Conductivity averaged 1,290 μmhos/cm. The average water temperature varied from 12 C to 17 C, averaging 14 C. The pH values ranged from 6.8 to about 7.5 for the wells tested during final pumping tests.

Upper aquifer pumping tests in holes G-S 12 and CE 705-A produced the lowest temperature water, averaging about 14 C. G-S 4-5 produced water at a relatively constant value of 17 C. In contrast, TO 3 showed fluctuating temperature values that average 23 C. Conductivity from G-S 12, CE 705-A, and G-S 4-5 ranged from about 1,350 μmhos/cm to 1,750 μmhos/cm. TO 3, however, averaged higher, 3,500 μmhos/cm. The affects of the formal upper aquifer pumping tests were observed only in nearby holes. The average T and S during drawdowns was 15,300 gpd/foot and 6.8×10^{-5} respectively. The average T and S during recovery was 16,900 gpd/ft. and 5.97×10^{-5}, respectively.

Water level changes in the upper aquifer were investigated using hydrographs, curve fittings, and residual analysis. In many cases the trend of the water level variations in holes are an exponential rise, with a sinesoidal component superimposed, as illustrated on Figure 2.51. The exponential rise in water levels in many holes is due to recovery from connection with the lower aquifer prior to late 1974. The periodic effect on water level rise, whether exponential, periodic, or a combination, and the extent of these influences appear to be a function of location.

RESIDUAL WATER LEVELS
UPPER AQUIFER



*RESIDUAL FROM EXPONENTIAL CURVE FIT
'RESIDUAL FROM LINEAR CURVE FIT

MEASURED WATER LEVELS
CORRELATION MATRIX (r)

	G-S 1	CE-708	AM-3	G-S 9	G-S 6
G-S1		.89	.69	.46	.09
CE-708			.80	.13	.13
AM-3				.04	.06
G-S 9					.28
G-S 6					

RESIDUAL WATER LEVELS
CORRELATION MAYTRIX (r)

	G-S 1	CE-708	AM-3	G-S9	G-S 6
G-S 1		.80	.60	.64	.28
CE-708			.40	.43	.54
AM-3				.35	.26
G-S 9					.35
G-S 6					

FIGURE 2.51

UPPER AQUIFER RESIDUAL WATER LEVEL AND CORRELATION MATRICES

A group of static water level measurements in the west central portion of the tract show distinct periodic water level variations. The aquifer in the southeastern corner of the tract appears to have primarily exponential recovery.

Most of the area of the upper aquifer in Tract C-a on the average, has a rising water level rather than declining water level, (Figures 2.52 and 2.53). The rising trend of water levels was reversed in many holes starting in April and continuing through July 1976. During the latter part of water year 1976, upper aquifer water level over most of the tract was declining. This is probably due to proportinally greater influence of seasonal water level variation over the exponential recovery from aquifer interconnection.

All of the pre-lease exploration holes on and near the tract were left open so that a direct path existed between the two deep oil shale aquifers. Estimates of the rate of flow between the aquifer were available from interpretation of spinner logs. Most holes that had multiple runs of the spinner logs, showed a decrease in flow with time. An estimate of the average flow is about 50 gpm in each hole. Several of the holes were open for periods of up to three years. The estimated total flow between the two aquifers is about 5,000 acre-feet from the upper aquifer into the lower aquifer. When the holes were completed in October and November of 1974 and the aquifers isolated, recovery began in both the upper and lower aquifers.

Since there was little information on a wide areal basis on the upper aquifer transmissivity, estimates of this parameter were made using the method of objective function minimization. Several assumptions were made in order to simplify the analysis of transmissivity, including the following: 1) 11 wells, AM-2A, AM 3, CE 701, CE 702, CE 705-A, CE 707, CE 708, CE 709, TO-1, TO-2, and TO-3 showed average downward flows of 50 gpm for two years prior to shut in; 2) transmissivities and storage coefficients were constant. An interference type analytical model using the Theis equation was constructed and was calibrated against observed drawdowns in G-S 2-3, G-S 12, G-S 11, and G-S 15. The calibration was done against the gradient over time in order to minimize the effects of the storage coefficient. The optimum transmissivity and storage coefficient found was T = 3,000 gpd/ft and S = .001. All values were corrected for recovery effects using standard methods. A second estimate of T and S was made using the data for 1 year from G-S 2-3 and the results agree with those listed above.

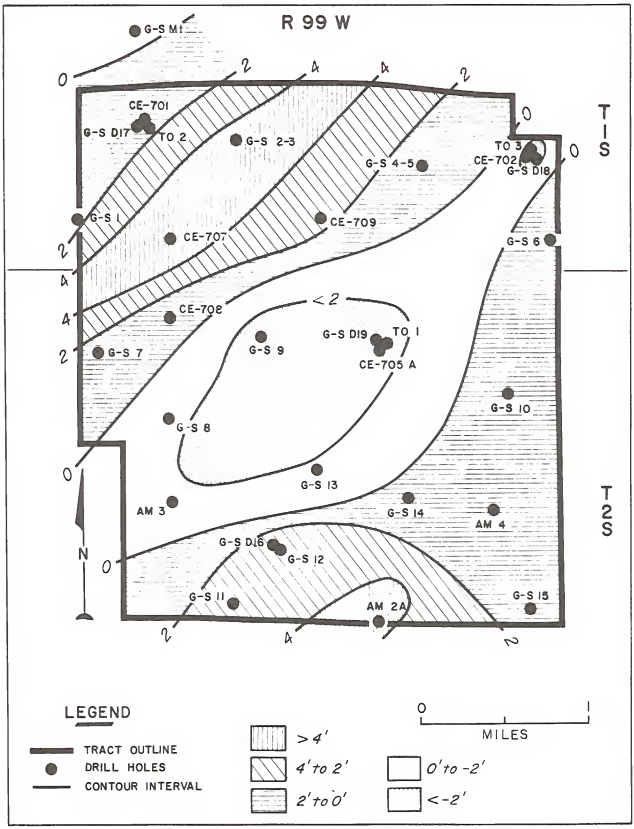


FIGURE 2.52

WATER LEVEL CHANGES IN THE UPPER AQUIFER, NOVEMBER 1975 TO NOVEMBER 1976

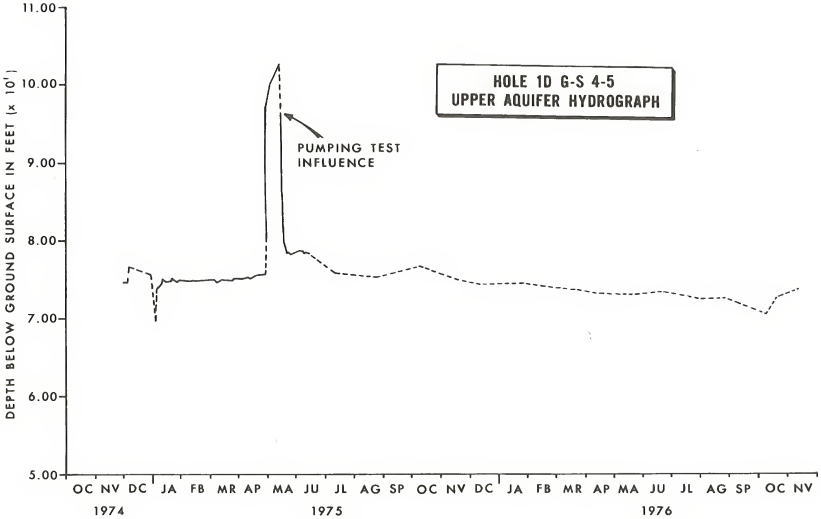


FIGURE 2.53

UPPER AQUIFER HYDROGRAPH G-S 4-5

III. LOWER AQUIFER

The lower aquifer includes water-bearing zones with similar water quality and temperature characteristics and its stratigraphic limits range from the bottom of the R-4 zone to the Blue marker.

Quality of water during drilling was poorer than upper aquifer water. Water from G-S D16, G-S D19, and G-S D18 had relatively stable pH, around 7.5. G-S D17 fluctuated between a pH of 6.0 and 7.3.

Temperature of G-S D19 water increased gradually from 17 C to 19 C, while temperatures in the other wells fluctuated: G-S D16 ranged from 24 C to 27 C and stabilized at 27 C about mid-test; G-S D17 ranged from about 13 C to 18 C; and G-S D18 ranged from 28 C to 30 C, and stabilized at 30 C at mid-test.

Conductivity of G-S D17 water was generally stable at 1.700 μmhos/cm. G-S D18 conductivity stabilized just less than 5,000 μmhos/cm. G-S D19 water conductivity gradually increased from 1,800 μmhos/cm to 2,400 μmhos/cm. G-S D16 conductivity gradually dropped from about 4,200 to 3,800 μmhos/cm.

Each of the formal pumping tests generally affected all of the observation holes with the exception of G-S M2 and G-S M3. The lack of affect on these holes is probably due to the partial penetration of the lower aquifer by these holes resulting in a poor hydrologic connection with the aquifer. The average transmissivities are less than the upper aquifer values, with an average T of 9,572 gpd/ft., and an S of 2.0×10^{-4}. The values of transmissivity were generally higher during recovery than during drawdown and are probably due to the lowering of piezometric level of the lower aquifer during pumping, resulting in the aquifer never fully recovering from the pumping (Figure 2.54).

A step drawdown test was conducted in G-S D16. The results indicate an average transmissivity of 15,500 gpd/ft.. The average drawdown, T and S for the long-term drawdown test of G-S D16 were 6,500 gpd/ft. and 1.19×10^{-7} respectively.

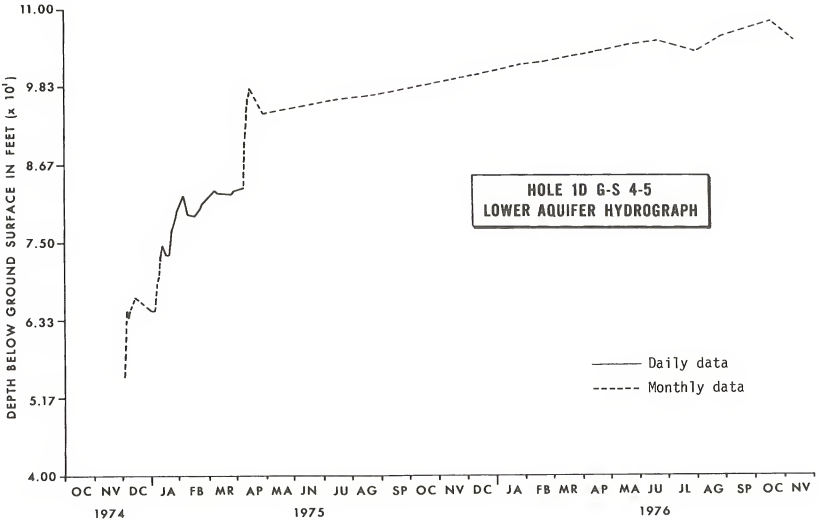


FIGURE 2.54

UPPER AQUIFER HYDROGRAPH
G-S 4-5

Lower aquifer water levels changes were investigated using hydrographs and best fit curve analysis. The changes in water levels have primarily followed an exponential decrease. Figures 2.55 and 2.56, when compared, show the correlation between measured and calculated water levels. In general, water levels have been higher than predicted by a foot or so. Other evidence, Figure 2.57 suggests that primarily exponential water level decline also has a cyclical component; i.e., $Y = Ae^{-xt} + C \cos wt$ where $A \gg C$. These results suggest that the lower aquifer had developed a mound of water due to the connection of the lower and upper aquifer prior to mid-1974, and since then has been tending toward equilibrium. Superimposed on this decline is a periodic water level change possibly due to seasonal recharge. The seasonal component of fluctuation is generally less than one foot in magnitude.

CONCLUSIONS

Three significant aquifer systems were found to be present on Tract C-a. They are; the alluvial aquifers, the upper oil shale aquifer, and the lower oil shale aquifer. The alluvial aquifers were found in the main gulches. The upper oil shale aquifer is in the vicinity of the Mahogany zone while the lower oil shale aquifer is associated with R 3 zone. Both of the deep oil shale aquifers average approximately 200 feet in thickness and are artesian.

All three of the aquifer systems are considered tributary, i.e., waters pumped from these aquifers will affect the direction or rate of surface water flow within a period of 40 years. In general, both conductivity and temperature increased with the depth of the aquifer. The testing program indicated transmissibilities of the upper aquifer to average 2,500 gallons per day per foot gpd/foot and the lower aquifer to average 7,000 gpd/foot.

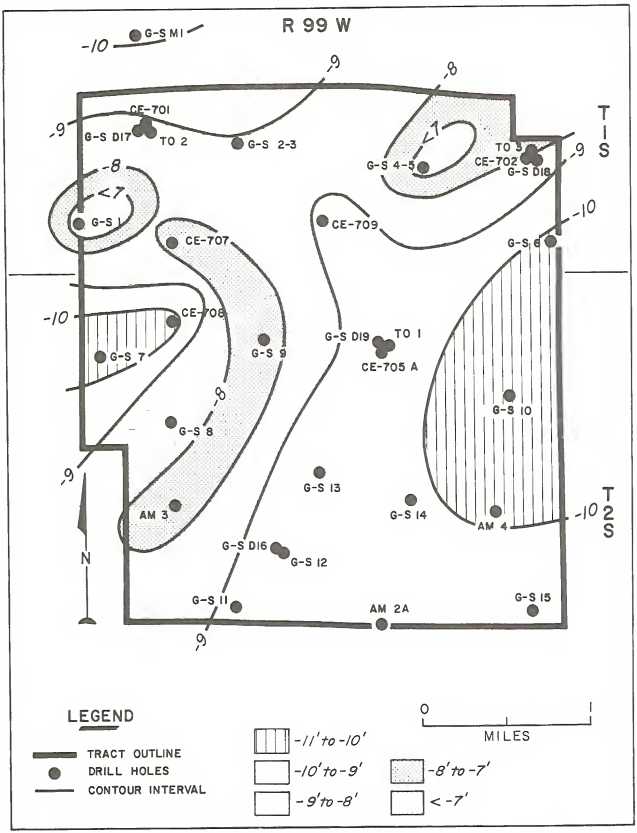


FIGURE 2.55
WATER LEVEL CHANGES IN THE LOWER AQUIFER, NOVEMBER 1975 TO NOVEMBER 1976

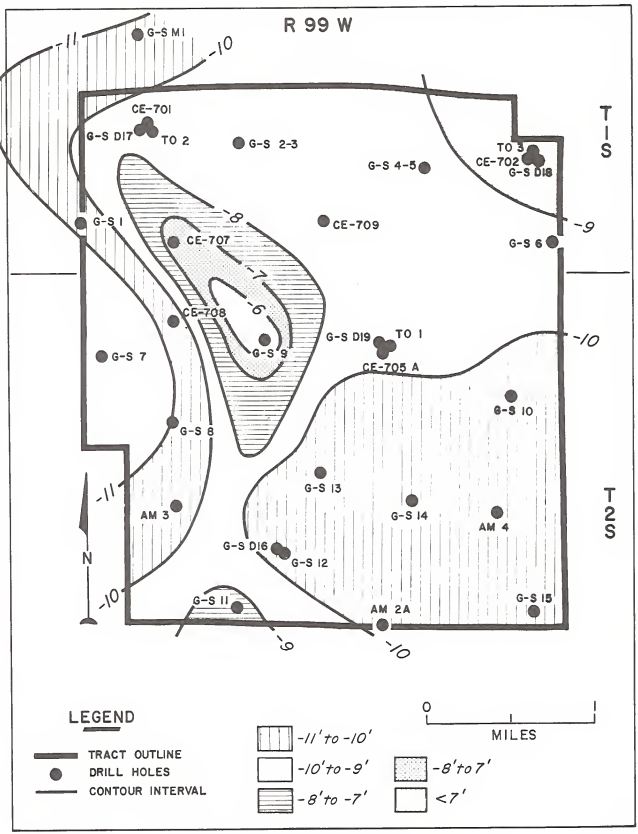


FIGURE 2.56

EXPECTED WATER LEVEL CHANGES, NOVEMBER 1975 TO NOVEMBER 1976

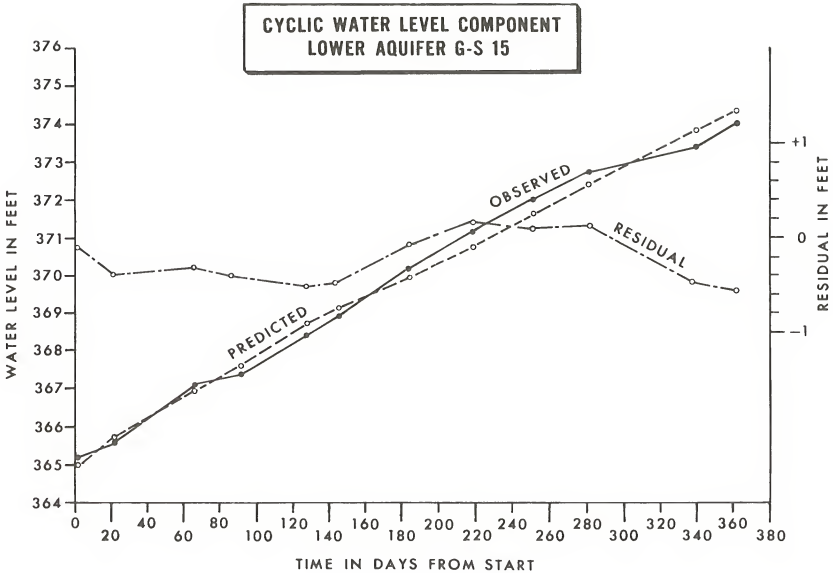


FIGURE 2.57

CYCLIC WATER LEVEL COMPONENT, LOWER AQUIFER, G-S 15

CHAPTER 6 - GROUNDWATER QUALITY

ABSTRACT

To determine areal and time variations in water quality within aquifer systems on Tract C-a to satisfy lease stipulations, and for evaluating potential tract development, a groundwater quality baseline monitoring program was established. Aquifer water quality sampling was accomplished during drilling, aquifer tests, and during the two-year baseline monitoring programs. Samples were collected using flow-through bailer tools, and samples were preserved using standard chemical preservatives. Analyses were performed using standard spectrographic and wet chemical techniques. Quality control following analysis included cation-anion balance, TDS versus conductivity comparison, and TDS calculated versus TDS measured. It was possible to define the typical water type of each aquifer. In some specific sampling sites a combination of water types exists. In general, the lower aquifer is of poorer quality (sodium bicarbonate type) than upper or alluvial aquifer water quality. Structural control seems to play an important role in deep aquifer water quality distribution. This is most apparent in upper aquifer areal quality distribution. A distinct connection between upper and lower aquifers exists in the northeastern tract corner. A distinction between deep and alluvial aquifer quality appears to be in the relation between Ca, and Na and TDS. Statistical analysis of these shows an inverse correlation for deep aquifers and a direct correlation for the alluvial aquifer. Alluvial water quality has distinct water quality seasonal variation. These variations differ between different alluvium.

The groundwater quality baseline monitoring program was undertaken in order to determine areal and time variations in water quality within each of the three aquifer systems. This water quality baseline is necessary for evaluating potential impacts of dewatering for oil shale development and as a basis for

comparison after oil shale development begins. The sampling program was initiated during the exploratory coring and aquifer testing programs, commencing in the summer of 1974. Beginning in March 1975, monthly samples from each of the deep oil shale aquifer monitoring holes were collected for a period of six months. After this initial period, the sampling frequency was reduced to once every six months. Monitoring holes in the alluvium were sampled monthly for the first year, decreasing to quarterly sampling during the second year, except for the flash flood and snowmelt season when monthly sampling was required. These monitoring samples were analyzed for chemical constituents as required and approved by the AOSS.

WATER QUALITY

The three aquifer systems (upper and lower oil shale aquifers and the alluvial aquifers) were sampled using three methods. Water quality samples were collected from the circulation line generally four times during the drilling or coring of each hole. Samples were also collected for analysis during the aquifer testing program. The majority of the water quality information was derived from the monitoring program, where samples were collected by bailing. These completion methods have been described in previous reports.

The results of wet chemical and spectrographic chemical analyses are stored on a computerized data base for ease in retrieval and analysis. The water quality data base consists of about 600 individual analyses so that for meaningful interpretation, statistical methods were necessary.

The results of wet chemical analyses of monitoring program samples were subjected to several quality assurance techniques. The balance between anion and cation totals was checked and found to be within 10 percent for the majority of the samples. For those samples where this 10 percent tolerance level was exceeded, the lab reports and lab workbooks were checked to assure the difference was not of a clerical nature. As an additional check on the accuracy of the analyses, a comparison was made between calculated (sum of constituents) dissolved solids and residue on evaporation of filtered samples. The ratio of TDS to conductance was also examined, since specific conductance was measured in the field. In order to avoid the introduction of variance due to the sampling method, only those samples collected from the monitoring holes by bailing

were used for population estimates. This was done because there is a high probability that many initial samples collected during the drilling and aquifer testing do not represent natural water quality in the aquifer.

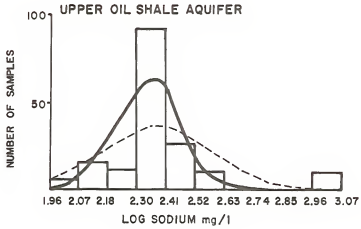
The most probable concentration of given parameters, both at a single hole and within a single aquifer, was calculated assuming a log-normal distribution for all parameters except depth to water, pH and temperature. The use of the log-normal statistical model for water quality parameters is discussed in the Surface Water Quality chapter. In addition, when calculating the most probable values for aquifers, the method of nonlinear least squares (Snyder 1972) was used in order to obtain a better description of the probability density function.

Figure 2.58 shows a histogram of observed Na concentrations (after log transformation) for monitoring program samples for the upper and lower oil shale aquifers and the alluvial aquifers. Also shown are the standard method of moments and the nonlinear least squares probability density function. The nonlinear least squares method generally provides a better description of the overall frequency distribution and was used as the basic statistical technique in subsequent tables. In order to not have population estimates biased by extreme outliers, the statistics were corrected to remove those values with a probability of occurrence of less than 0.0001 based on the final probability function.

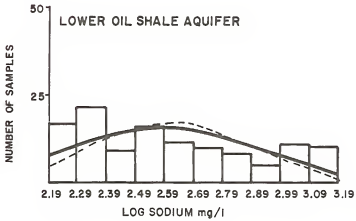
I. ALLUVIAL AQUIFER

The alluvial aquifers occur along major stream valleys and are quite variable in thickness. On Tract C-a, alluvium is present along Corral Gulch, Dry Fork, Rinky Dink Gulch, and Box Elder Gulch. The location of tract monitoring holes is shown on Figure 2.47. Monitor hole S-7 was the only hole with sufficient production to allow sampling during drilling. The remainder of the holes have only been sampled during the monitoring program. In order to describe the alluvial aquifer water quality applicable to Tract C-a, only analyses from holes S-7, S-8, and S-11 were analyzed.

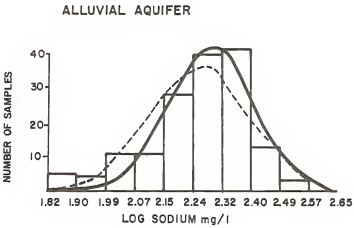
The alluvial holes are in hydraulic connection with the streams that occupy their valleys and thus show seasonal variation. Figure 2.59 is a composite plot of TDS concentration as a function of time for S-7, S-8, and S-11.



	METHOD OF MOMENTS	NON LINEAR LEAST SQUARES
GEOMETRIC MEAN	232.8	212.4
GEOMETRIC DEVIATION	1.61	1.30



GEOMETRIC MEAN	417.8	396.7
GEOMETRIC DEVIATION	1.96	2.12



GEOMETRIC MEAN	179.5	195.3
GEOMETRIC DEVIATION	1.40	1.32

PROBABILITY DENSITY FUNCTION

- - - - METHOD OF MOMENTS

——— NON LINEAR LEAST SQUARES

FIGURE 2.58

FREQUENCY DISTRIBUTIONS OF SODIUM IN SAMPLES FOR THREE AQUIFERS, TRACT C-a

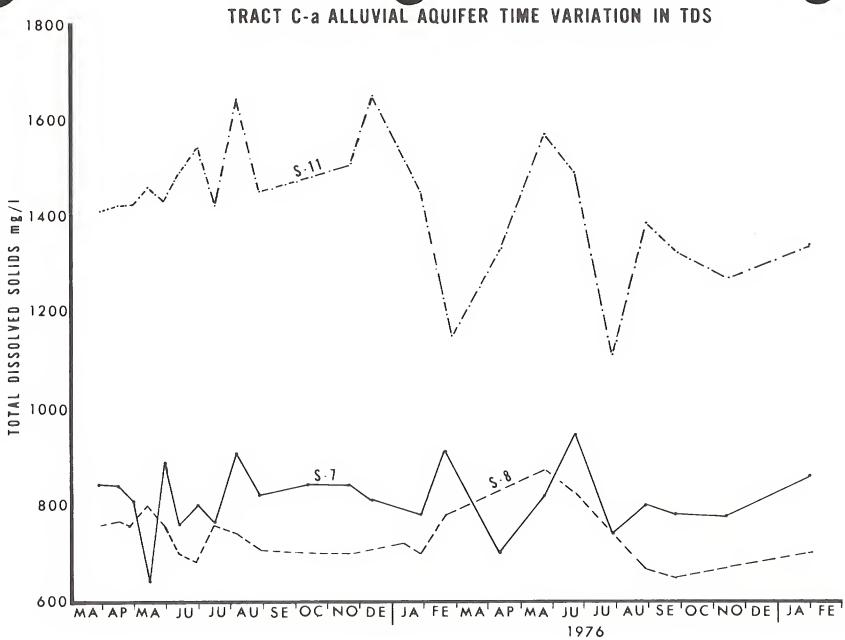


FIGURE 2.59

TOTAL DISSOLVED SOLIDS VS. TIME FOR ALLUVIAL AQUIFERS

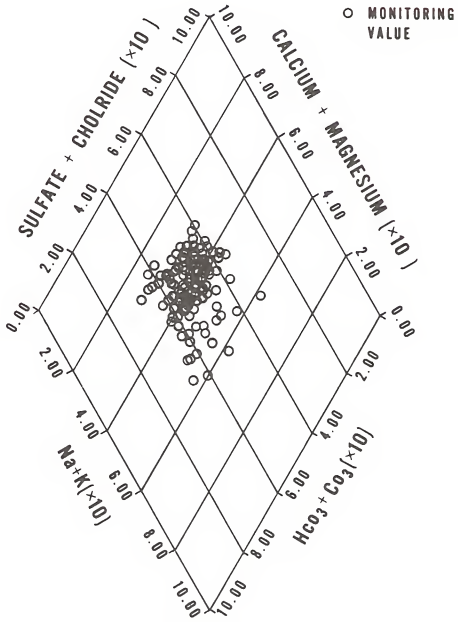
No simple seasonal variation is present in TDS; however, S-11 appears to show a trend of lowering TDS concentration over the baseline period. The downgradient well (S-11) generally shows the highest concentration of all parameters of the three monitoring holes.

Figure 2.60 shows the trilinear plot of all monitoring program analyses for the alluvial aquifer. The analyses plot is a fairly dense cluster similar in position to that encountered in the upper aquifer, except slightly enriched in Ca and Mg.

Table 2.80 shows the observed maximum and minimum values, geometric mean, and deviation, and number of analyses used in calculating the statistics. Outliers were deleted in calculating the statistics; however, they are retained in the maximum and minimum columns. The criterion for deletion was a probability of occurrence of less than 0.0001. Only S-7, S-8, and S-11 were used for this table because these were the only near tract monitoring holes near the tract in which water was encountered.

Time trend plots of the concentrations of chemical constituents show many similar cyclical relationships and show a difference between gulch alluvia (Figure 2.61) The cyclical trends which have similar periods of constituent concentrations are hardness, Mg, HCO_3, and temperature. These constituents usually reach peak concentrations in October and minimum concentrations in March. Although Box Elder Gulch and Corral Gulch constituent concentrations have similar periods, the mechanism may be different by which these concentration variations occur.

The degree of alluvial saturation at G-S S-7 in Corral Gulch inversely follows trends of water constituent concentration. This implies that during periods of high saturation due to snowmelt runoff, the alluvium is being flushed. During periods of low saturation water constituent concentrations reach a maximum level due to the high proportion of groundwater contribution. The information gained from the trend plots from Box Elder alluvium indicate that the maximum concentration of many chemical constituents lag behind maximum alluvial saturation by about 70 days.



COMBINED ALLUVIAL AQUIFER TRILINEAR DIAGRAM

FIGURE 2.60

TABLE 2.80

BASELINE GROUND WATER WATER QUALITY SUMMARY, ALLUVIAL AQUIFERS ON TRACT C-a

Param. No.	Item	High	Low	Geometric Mean	Geometric Deviation	No. of Analyses
410	Alkalinity (mg/l)	880	310	383	1.17	67
1106	Aluminum (mg/l)	1200	< 100	142	2.14	11
71846	Ammonia (NH4) (mg/l)	6.4	< 0.1	0.36	2.49	49
1000	Arsenic (ug/l)	< 100	< 10	< 10.9	1.56	53
1005	Barium (ug/l)	< 1000	< 1000	< 1000	1.00	45
1010	Beryllium (ug/l)	600	< 20	106	5.48	3
440	Bicarbonate (mg/l)	680	360	458.7	1.19	67
1015	Bismuth (ug/l)	--	--	--	--	--
310	BOD (mg/l)	3.90	3.80	3.85	1.02	2
1020	Boron (ug/l)	27000	< 10	190	6.92	65
71870	Bromide (mg/l)	0.9	< 0.01	0.15	4.11	8
1025	Cadmium (ug/l)	1100	<10	17.1	2.25	54
915	Calcium (mg/l)	210	39	96.4	1.38	67
445	Carbonate (mg/l)	48.0	< 0.1	0.26	8.23	67
940	Chloride (mg/l)	41.0	1.3	12.8	1.73	65
1030	Chromium (ug/l)	200	<10	11.06	1.54	54
340	COD (mg/l)	85	5	16.4	2.18	11
31615	Coliform, Fecal (Col/100 ml)	40	<10	20	2.67	2
31501	Coliform, Total (Col/100 ml)	250	20	71	5.97	2
80	Color (PCU)	--	--	--	--	--
95	Conductivity, Spec. (umhos)	2252	860	1288	1.32	67
1040	Copper (ug/l)	2400	<10	11.9	1.33	56
720	Cyanide (mg/l)	0.02	< 0.01	0.01	1.0	55
300	Dissolved Oxygen (mg/l)	--	--	--	--	--
950	Fluoride (mg/	0.7	0.1	0.26	1.73	66
1120	Gallium (ug/l)	--	--	--	--	--
1125	Germanium (ug/l)	--	--	--	--	--
900	Hardness (Ca, Mg) (mg/l)	810	280	447.7	1.38	62
1046	Iron (ug/l)	28000	< 50	1029	10.86	67
625	Kjeldahl Nitrogen (mg/l)	8.8	< 0.10	1.78	3.10	22
1049	Lead (ug/l)	1000	10	137.8	3.45	56
1130	Lithium (ug/l)	< 100	< 100	< 100	1.01	11
925	Magnesium (mg/l)	145	3.7	57.04	1.78	65
1056	Manganese (ug/l)	15000	< 50	575	6.98	64
38260	MBAS (mg/l)	< 0.01	< 0.01	< 0.01	1.0	2
71890	Mercury (ug/l)	< 10	< 1	< 2.56	2.69	56
1060	Molybdenum (ug/l)	< 100	< 100	< 100	1.0	6
1065	Nickel (ug/l)	200	10	53.5	2.27	45
71851	Nitrate (NO_3) (mg/l)	165	0.1	3.9	2.21	61
613	Nitrogen - Nitrite as N (mg/l)	150	< 0.01	0.22	14.74	19
631	Nitrite Plus Nitrate (N)(mg/l)	--	--	--	--	--
608	Nitrogen, Ammonia (mg/l)	5.3	< 0.10	0.36	3.61	14
607	Nitrogen, Organic (mg/l)	--	--	--	--	--
1330	Odor (severity)	--	--	--	--	--
550	Oil and Grease (mg/l)	--	--	--	--	--
	Organic Carbon (mg/l)					
681	Dissolved	292	2.0	18.7	3.44	55
689	Suspended	--	--	--	--	--
680	Total	--	--	--	--	--
	Pesticides (ug/l)	--	--	--	--	--
400	pH*	7.2	6.0	6.32	0.34	63
32730	Phenols (ug/l)	13	<1	2.09	3.12	11
	Phosphate (mg/l)					
660	Dissolved (PO_4)	0.10	0.10	0.10	1.0	20
70507	Ortho (P)	0.30	<0.01	0.10	1.41	65
665	Total (P)	--	--	--	--	--
935	Potassium (mg/l)	14.0	<1.0	3.66	1.99	22
	Radioactivity					
1503	Gross Alpha (pc/l)	31.0	0.2	7.34	2.47	45
9503	Radium 226 (pc/l)	1.0	0.1	0.26	2.14	27
80030	Natural Uranium (ug/l)	--	--	--	--	--
3501	Gross Beta (pc/l)	35.0	1.0	9.5	2.54	13
80050	Sr^{90} (pc/l)	--	--	--	--	--
3515	Cs^{137} (pc/l)	--	--	--	--	--
1145	Selenium (ug/l)	< 100	<10	< 10.4	1.36	56
955	Silica (SiO_2)	41.0	16.0	29.2	1.18	67
1075	Silver (ug/l)	< 100	<10	< 13	1.78	45
930	Sodium (mg/l)	350	66	151.1	1.57	67
931	Sodium Adsorption Ratio	--	--	--	--	--
540	Solids, Dissolved (mg/l)	1650	640	777	1.15	67
1080	Strontium (ug/l)	5000	1400	2495	1.56	6
945	Sulfate (mg/l)	720	150	297	1.84	67
746	Sulfide (mg/l)	1.60	< 0.10	0.16	2.56	11
11	Temperature (°F)*	57.2	42.0	48.8	2.91	67
1100	Tin (ug/l)	--	--	--	--	--
1150	Titanium (ug/l)	--	--	--	--	--
70	Turbidity (JTU)	--	--	--	--	--
1085	Vanadium (ug/l)	--	--	--	--	--
1090	Zinc (ug/l)	3200	10	292	3.46	55
1160	Zirconium (ug/l)					

* Normal mean and standard deviation

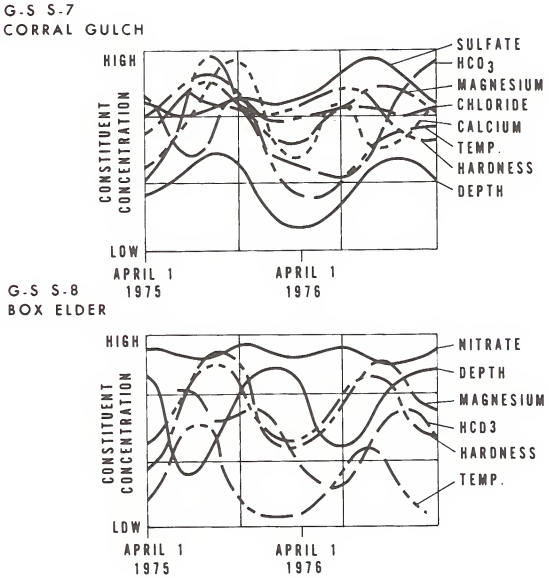


FIGURE 2.61

TIME TREND PLOTS FOR CONCENTRATIONS OF CHEMICAL CONSTITUENTS IN TRACT C-a ALLUVIUM

The degree of alluvial saturation of Box Elder Gulch is less than at Corral Gulch. Drilling results for the Box Elder Gulch alluvium indicated that most of the alluvium was clayey silt which was powdery dry. This implies that transmissivity at Box Elder G-7 S-7 alluvium is considerably less than at Corral Gulch G-S S-8, where drilling reports indicate the presence of some gravelly material. Peak saturation at Box Elder Gulch alluvium would be expected to be delayed from Corral east. Water level data suggest this delay to be at least a month, though the delay may also be a function of drainage orientation. The initial slow percolation of water into Box Elder alluvium causes an increase of water chemical constituent to maximum levels. Thereafter some percolation and groundwater flow causes flushing of the alluvium, though alluvial recharge is essentially over and water levels are decreasing.

Figure 2.62 is a sign correlation matrix for monitoring samples obtained from the alluvial aquifer. A plus sign indicates a direct correlation significant at the 5 percent level, while a minus sign indicates and inverse correlation significant at the same level. Numerous significant direct correlations exist between the major constituents. The only inverse correlation among the majors is that between Na and Ma. This is in contrast to a general pattern of correlations in the upper and lower alluvial aquifers as Ca, Mg, and So_4 are usually directly correlated with each other and, as a group, inversely correlated with the rest of the major anions and cations and with F and B. In general correlations with the heavy metals are inverse for reduced species such as cyanides (Cn), SO_4, NO_2, and NH_4.

Factor analysis including all monitoring samples from the alluvial aquifer was completed using 27 of the chemical parameters. A factor loading matrix with associated eigenvalues and communalities are shown on Table 2.81. As can be seen, the explained covariance or communality is relatively high for all parameters, with the exception of temperature and As. Factor 1 which explains approximately 20 percent of the variance, is composed mainly of conductivity, alkalinity, Na, SO_4, and gross alpha. Less important loadings were present on Ca, Ma, Si, Cu, and Se. This is in contrast to the results of factor analysis on the upper and lower aquifers in that a direct correlation was shown in the alluvial water between Ca, Mg, and

FIGURE 2.62

ALLUVIAL AQUIFER WATER QUALITY MONITORING PROGRAM SUMMARY

CORRELATION MATIRX

	Temperature	Conductivity	COD	pH	Alkalinity	Bicarbonate	Carbonate	TDS	Ammonia	Nitrite	Cyanide	Sulfide	Hardness	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Fluoride	Silica	Arsenic	Barium	Boron	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Molybdenum	Nickel	Silver	Strontium	Zinc	Aluminum	Lithium	Selenium	Gross Alpha	Gross Beta	Phenols	Phosphate	Ammonia	Nitrate	Bromide	Mercury
Temperature		+	+							-											+															+											+
Conductivity				+	+		+	-			+	+	+	+		+	+	-	+																+				+							-
COD			-						+			-	-				+		-						+	-	-			-						-							-	+		
pH						-			-					+						+							-					-								-						
Alkalinity				+	-	+					+	+	+	+		+	+		+				+					+														-					
Bicarbonate				-	+						+		+	+		+	+		+	-	+					+	+	+																		
Carbonate																	+				-				+									. +											+	+
TDS												+	+	+	+		+	+			+						+		+					+			-	+			+		+		-
Ammonia-N										-	-		-		-	+		-	-																	-				-						-
Nitrite																+	+		-							-	-		-	-				+	-	-					+		-	+		
Cyanide																+									+		-																			-
Sulfide																+									-		-		-	-					-											-
Hardness													+	+	+		+	+		+	-		+			+		+							+	+				+			+		+	+	-
Calcium															-	+		+		+					+	+	+		+		+				-	+				+							
Magnesium														+	+	+	+	+					+												+					+			+		+	-
Sodium																	+	+		+			+												+				-	+				+		
Potassium																										-									+							+		+		+
Chloride																		+		+	-												+	-	+				+	-		+				
Sulfate																				+							+	+							+				-	+			+	+	+	-
Fluoride																				+						-		+					-										-	-		
Silica																													+	+					+				+							
Arsenic																																	+													
Barium																																														
Boron																															-	-		-	+		-									+
Cadmium																											+		+	+	+	+		+	+				+		-		+	+	+	-
Chromium																												-															+	-	+	
Copper																												+	+	+		+			+					+					+	-
Iron																													+	+		+	+		+					+		-			+	+
Lead																														+		+	+		+					+					+	
Manganese																																+			+	+				+		-	+			
Molybdenum																																														
Nickel																																			+					+			+			-
Silver																																			+								+			-
Strontium																																										+		+		
Zinc																																							+				+		+	-
Aluminum																																														
Lithium																																														
Selenium																																														+
Gross Alpha																																												+		-
Gross Beta																																														-
Phenols																																														
Phosphate																																											+	+		-
Ammonia																																										-				
Nitrate																																										-				
Bromide																																														

+ is direct correlation significant at 5% level

- is inverse correlation significant at 5% level

TABLE 2.81

VARIMAX FACTOR LOADING MATRIX OF CHEMICAL CONSTITUENTS FROM TRACT C-a ALLUVIAL MONITORING PROGRAM*

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Communality
Temperature			.48060							.31642
Conductivity	.90257									.87377
pH			.75000	-.23901					-.21357	.70661
Alkalinity	.83509						.27183			.81786
Calcium	.29301			.75227						.68815
Magnesium	.41774			-.70516			.42227			.87156
Sodium	.86339									.84491
Chloride	.34717	.25554				.26936	.28837	.52294		.62413
Sulfate	.99449									1.000
Fluoride		-.20560			-.71631	-.21046				.65570
Silica	.49967	.21845	.50078						.20187	.63464
Arsenic								.55529		.32284
Boron	.30611	-.27914				.39644				.40765
Cadmium		.27550		.34123	.32733	-.26669	.34944			.52485
Chromium						.66621				.47569
Copper	.22969	.60215	-.54565		-.21993					.83637
Iron		.55690								.44480
Lead		.54811	-.26401							.45851
Manganese		.64941		.23559			.24633		.41598	.76970
Nickel		.56622	-.31566		.23625		.23376		.36262	.73627
Zinc		.76844				-.28368				.73720
Selenium	-.21265								-.52979	.33728
Gross Alpha	.52938	.22587	-.29299	.31745			.40384	-.30144		.77710
Phosphate							.59392			.37761
NH4					.67270					.49688
Nitrate	.20082				.35100	-.26355	.38071		-.22042	.44886
Mercury		-.26526	.23578			.56609	-.40870	.25691		.78475
Percent variance explained	32.1	20.5	11.7	9.3	6.9	6.1	5.1	4.6	3.8	
Cumulative percent	32.1	52.6	64.3	73.6	80.9	86.6	91.7	96.2	100.0	

*Loadings less than 0.2 omitted

Na. Factor 2 which explains approximately 13 percent of the variance, is dominantly composed of heavy metal components. Factor 4 shows an inverse correlation between pH and Ca. A smaller subset of parameters was retained for another factor analysis, the results of which are shown on Table 2.82.

Factor 1 which accounts for 65 percent of the explained covariance is mainly composed of alkalinity, TDS, Na, and SO_4. Factor 2 is dominantly composed of Ca and Mg, which are inversely correlated. Factor 3 shows a simultaneous direct relationship between Cl, F, and B.

Differences in overall water quality between S-7 and S-8, representing quality above Tract C-a and S-11 and S-12, representing quality below Tract C-a are shown on Figure 2.63. In this figure the average score for factor 1 both upstream and downstream from the tract are shown as a function of time. The holes down-gradient from the tract have a higher score on factor 1 at all times, due to higher values for alkalinity, TDS, Na, and SO_4. This down-gradient differnece is probably due to increased discharge from the oil shale aquifers to the alluvium.

Figure 2.64 shows the average factor score as a function of time. The plot is a composite of information from monitoring holes S-7, S-8, S-11, and S-12. Several trends are apparent on this composite factor score hydrograph. A seasonal component is present on factor scores 1 and 2 with seasonal peak on 1 occuring during snowmelt and the peak on 2 occurring at the end of the summer. Factor score 3 shows a general decreasing trend over the baseline period. The major contributors of factor 1 are TDS, So_4, alkalinity and Na. The influx of snowmelt into the alluvium could be responsible for the seasonal rise by leaching previously deposited minerals. Factor score 2 is composed mainly of Mg with a strong negative component for Ca. There is a general inverse correlation between factor scores 1 and 2, which suggests mutually exclusive processes are responsible for each of these factors. The decreasing trend for factor 3 is due to increasing F concentration due to flushing the alluvial aquifer of deep drilling effluent.

TABLE 2.82

VARIMAX FACTOR LOADING MATRIX OF CHEMICAL DATA

FROM TRACT C-a ALLUVIAL AQUIFER MONITORING PROGRAM*

	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Alkalinity	.52988				.30659
pH				.57330	.34913
TDS	.98956				.99778
Calcium	.23342	-.59539			.42668
Magnesium	.42825	.79648			.83787
Sodium	.87843				.77727
Chloride	.43077		.27999		.30576
Sulfate	.93925				.92948
Fluoride			.36166		.14450
Silica	.42133		.44656	.28313	.46435
Boron					.06002
Percent variance explained	65.0	19.5	8.9	6.7	
Cumulative percent	65.0	84.4	93.3	100.0	

*Loadings less than 0.2 omitted

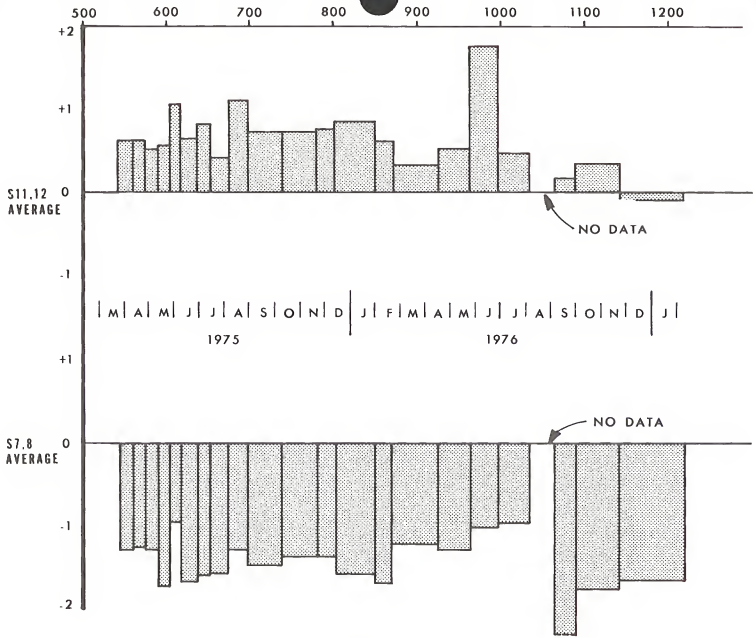


FIGURE 2.63

ALLUVIUM AQUIFER WATER QUALITY FACTOR SCORE COMPARISON

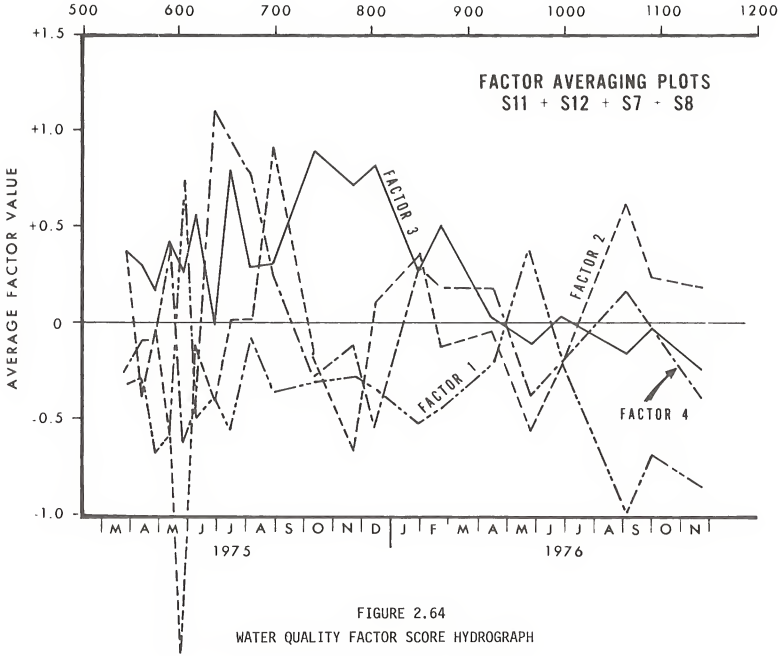


FIGURE 2.64
WATER QUALITY FACTOR SCORE HYDROGRAPH

FIGURE 2.70

UPPER AQUIFER WATER QUALITY MONITORING PROGRAM SUMMARY
CORRELATION MATRIX

	Temperature	Conductivity	COD	pH	Alkalinity	Bicarbonate	Carbonate	TDS	Ammonia	Nitrite	Cyanide	Sulfide	Hardness	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Fluoride	Silica	Arsenic	Barium	Boron	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Molybdenum	Nickel	Silver	Strontium	Zinc	Aluminum	Lithium	Selenium	Gross Alpha	Gross Beta	Phenols	Phosphate	Ammonia	Nitrate	Bromide	Mercury
Temperature	+		+	+	+		+	+		-				-		-	+	+			-	+	+	+		+				-									+	+			+				
Conductivity			+	+			+								+		+	+	+	-	+	+		+							-				+					+	+		+				
COD									-								-						+			+		+									-			-		+				
pH		+	+	+				-		+	-	-	-	+		-		-	+		+			+				-											-				+	+	-	-	-
Alkalinity					+		+	+								+	+	+	-	+	+			+				-		-				+		-		+	+			+				
Bicarbonate							+	+							+		+	+	+	-	+	+		+												-		+	+			+				
Carbonate													-	-	-	+		+	-	+	-						+				-				+								+	+	-		
TDS													+	+		+	+	+		+	+			+							-				+					+	+	-	+				
Ammonia-N																-	+		-	-	+	+		+	+												+								-		
Nitrite																		+			-						-		-							-		+				+			+		
Cyanide																															-										-			+	+	-	-
Sulfide																							+										+	-								+					+
Hardness													+	+	-			-	+	-	+		-					+									-							-	-	+		
Calcium														+	-				+	-	+		-				-	+								-								-	-		+	
Magnesium															-		-	+	-	+	-		-																					-	+		-	
Sodium																+	+	-	+	+	-		+							-									+	+				+		-		
Potassium																										-		-							-	+						+		+	+	
Chloride																									-	+		+						-		-										+
Sulfate																			-		-		-				+	+										+				-	-	+		
Fluoride																				-			+	-				-		-									+	+		+	+		-	
Silica																													-					+	-				+	+	-					
Arsenic																																	+						+			+				
Barium																																														
Boron																																+		-	-							-				-
Cadmium																										+		+			+	+													-		
Chromium																											+		+						+		-			-	-						
Copper																												+	+			+			+	+				-							-
Iron																													+	+		+	-		+		-		+	+	-		-			+
Lead																																+			+								-		-	+
Manganese																																			+					-	-		-				
Molybdenum																																				+											
Nickel																																	+		+	-											-
Silver																																															
Strontium																																							+				-				
Zinc																																					-			-					-	+
Aluminum																																						-									
Lithium																																								+							
Selenium																																									-						
Gross Alpha																																							+			+					
Gross Beta																																										+					
Phenols																																														+	
Phosphate																																															
Ammonia																																														-	-
Nitrate																																															
Bromide																																															
Mercury																																															

+ is direct correlation significant at 5% level

- is inverse correlation significant at 5% level

TABLE 2.84

VARIMAX FACTOR LOADING MATRIX OF CHEMICAL DATA

FROM TRACT C-a UPPER AQUIFER MONITORING PROGRAM*

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Communality
Temperature	.60344							-.35135	.57762
Conductivity	.89943				.23631				.90069
pH	.29183	-.30251		-.63993					.65741
Alkalinity	.91917								.90816
TDS	.92300				.20952				.95784
Calcium		.86242		.31242					.87852
Magnesium		.49018	.22334	.36674	-.34554			.24025	.65107
Sodium	.84691	-.36506			-.20932				.95798
Chloride	.23540				.56226				.39936
Sulfate	-.24825	.36680		.85554					.97540
Fluoride	.45716	-.65686		-.30869					.80583
Silica	.48291	.64511			-.26124				.77140
Arsenic							.77086		.61411
Boron	.28438					.22392		-.56873	.48741
Cadmium						.51572			.28229
Chromium					.54850				.34721
Copper			.64758			.25853			.49476
Iron			.75937						.67693
Lead			.43479	.22810		.43647			.44007
Manganese	-.39515		.49243		.29310		-.21680		.57845
Nickel						.66608	.21380		.57156
Zinc						.35681		.40297	.44400
Selenium				.51094					.31753
Gross Alpha	.48978				-.24011				.34394
Phosphate				.51128			.27682		.37751
NH4	.41268	-.46244			.36616	-.40572			.69038
Nitrate				.30508					.16573
Mercury			-.56686		.51102			.37247	.76260
Percent variance explained	34.4	19.0	14.8	11.4	7.8	5.3	4.0	3.5	
Cumulative percent	34.4	53.4	68.0	79.5	87.3	92.5	96.5	100.0	

*Loadings less than 0.2 omitted

TABLE 2.85

VARIMAX FACTOR LOADING MATRIX OF CHEMICAL DATA
FROM TRACT C-a UPPER AQUIFER MONITORING PROGRAM*

	Factor 1	Factor 2	Factor 3	Communality
Alkalinity	.35096	.55634	.68922	.90771
pH	.68314			.47094
TDS		.80797	.52105	.92551
Calcium	-.69018		.53970	.75865
Magnesium	-.55934	-.21710	.29985	.44990
Sodium	.43085	.86632		.96802
Chloride		.37955		.15863
Sulfate	-.87641			.76932
Fluoride	.73166	.33249		.64684
Silica			.78376	.63224
Boron	.29512	.23591		.15424
Percent variance explained	51.7	35.9	9.4	
Cumulative percent	54.7	90.6	100.0	

*Loadings less than 0.2 omitted

was relatively low for Cl and B in this smaller subset of chemical parameters. A total of three factors was extracted explaining the percent of the total variance. Factor 1 shows a high direct correlation between F, Na, pH with a simultaneous high inverse correlation with SO_4, Mg, and Ca. The second factor extracted shows a major association between Na and TDS, while the third factor shows a less important association between Ca Mg and alkalinity with silica.

The map distribution of the 3 factor scores resulting from this smaller subset of parameters is shown on Figures 2.71, 2.72, and 2.73. The areal plot of factor score 1 shows a distinct association of high values on factor score 1 with an influence of leakage from the lower aquifer into the upper aquifer. High values for factor score 1 occur in the northeast corner of the tract. The lower values for factor score 1 tend to be associated with faulting in the central portion of the tract trending in a northwesterly direction. Factor score 2, which is dominantly a nacholite dissolution factor, shows high values on the down-gradient or eastern side of the tract with one anomalous high trending almost north-south present in G-S 9, G-S 13, G-S 14, G-S 12, and Am 2A. The general distribution of factor scores in the upper aquifer suggests that water quality is strongly controlled by structure.

Figure 2.74 shows the time trend of factor scores for averages of holes in these different structural settings. The holes near fault zones show a distinct difference in factor score 1 values with a distinctly higher score present. The holes located on the anticlinal axis show the only slight time trend, with an increase in factor score 3.

III. LOWER AQUIFER

Water chemistry analysis results and discussions have been presented on a quarterly basis in Progress Reports 1 through 9. Final composite and summary figures and tables for the lower aquifer sampling program are presented in this section. The frequency of sampling was the same as the upper aquifer. Table 2.86 is a summary of the lower aquifer constitutents based on the two-year monitoring program.

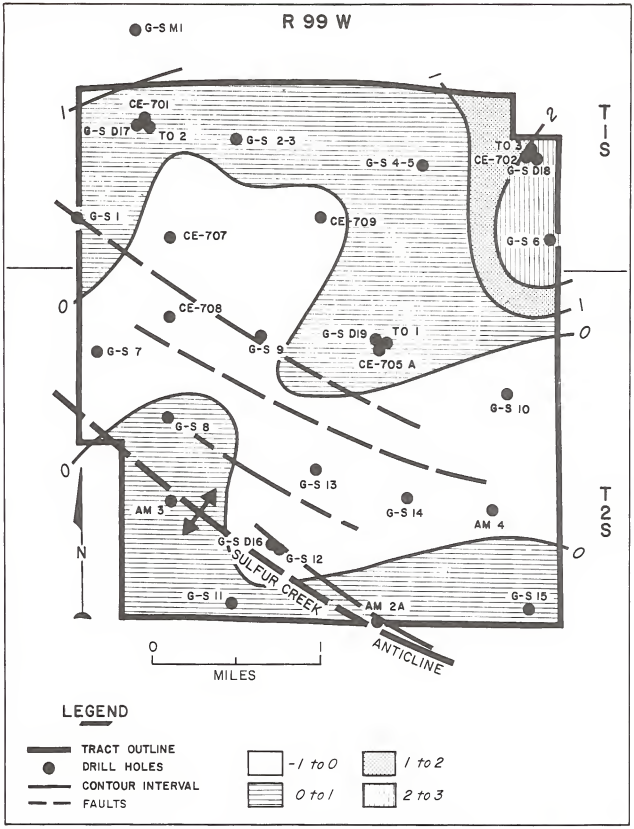


FIGURE 2.71

UPPER AQUIFER FACTOR 1 AREAL DISTRIBUTION

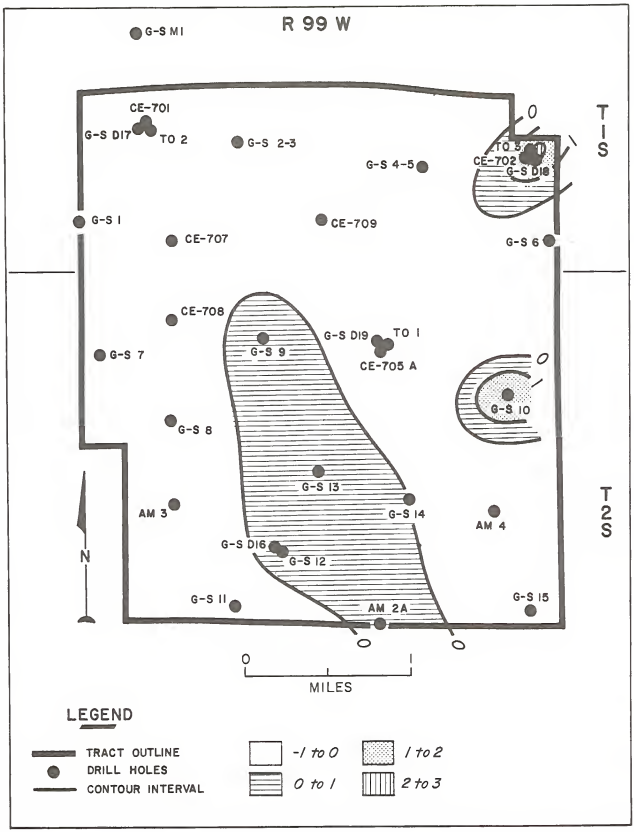


FIGURE 2.72

UPPER AQUIFER FACTOR 2 AREAL DISTRIBUTION

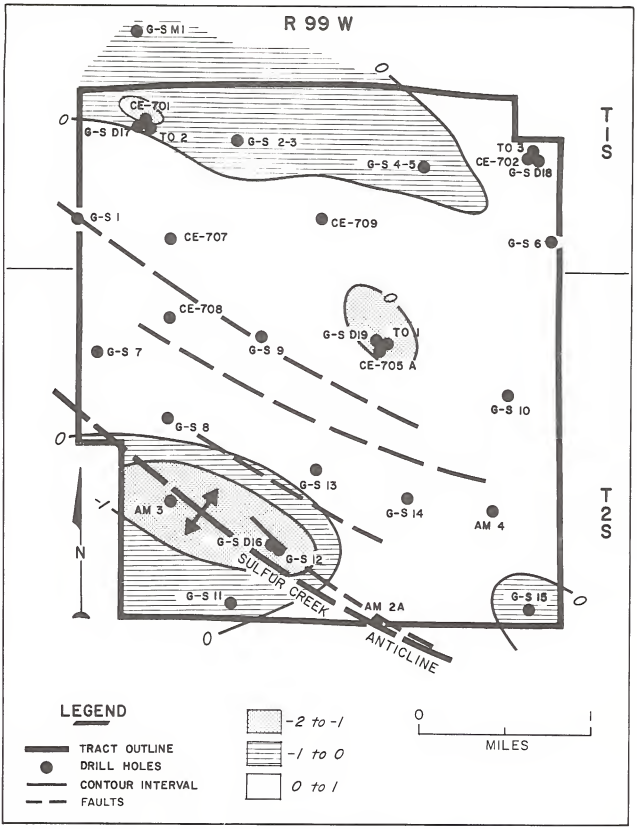


FIGURE 2.73
UPPER AQUIFER FACTOR 3 AREAL DISTRIBUTION

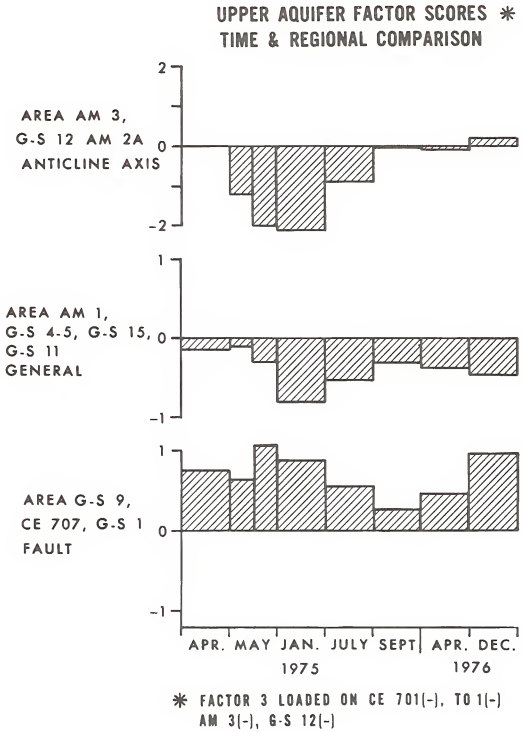


FIGURE 2.74
UPPER AQUIFER FACTOR SCORES

TABLE 2.86
BASELINE GROUND WATER QUALITY SUMMARY
LOWER OIL SHALE AQUIFER

Param. No.	Item	High	Low	Geometric Mean	Geometric Deviation	No. of Analyses
410	Alkalinity (mg/l)	4500	52	674	2.33	108
1106	Aluminum (mg/l)	1000	< 10	241	2.80	28
71846	Ammonia (NH_4) (mg/l)	9.6	0.02	0.59	2.45	89
1000	Arsenic (ug/l)	30	< 10	10	1.01	106
1005	Barium (ug/l)	< 1000	< 100	968	1.32	69
1010	Beryllium (ug/l)	< 100	< 100	--	--	1
440	Bicarbonate (mg/l)	3310	260	842	2.47	108
1015	Bismuth (ug/l)	--	--	--	--	--
310	BOD (mg/l)	--	--	--	--	--
1020	Boron (ug/l)	5700	10	841	4.35	108
71870	Bromide (mg/l)	< 0.1	< 0.02	< 0.05	2.23	34
1025	Cadmium (ug/l)	30	< 1	9.9	1.43	106
915	Calcium (mg/l)	98	0.80	8.8	2.21	108
445	Carbonate (mg/l)	710	< 0.1	68.83	2.33	108
940	Chloride (mg/l)	160.0	< 0.1	21.7	2.73	106
1030	Chromium (ug/l)	< 50	< 10	< 11.48	1.47	106
340	COD (mg/l)	92	< 0.1	12.9	3.65	38
31615	Coliform, Fecal (Col/100 ml)	--	--	--	--	--
31501	Coliform, Total (Col/100 ml)	--	--	--	--	--
80	Color (PCU)	--	--	--	--	--
95	Conductivity, Spec. (umhos)	5180	845	1459	1.78	108
1040	Copper (ug/l)	300	< 10	88.07	1.76	108
720	Cyanide (mg/l)	0.08	< 0.01	0.01	1.24	105
300	Dissolved Oxygen (mg/l)	--	--	--	--	--
950	Fluoride (mg/	85	0.3	14.69	3.38	108
1120	Gallium (ug/l)	--	--	--	--	--
1125	Germanium (ug/l)	--	--	--	--	--
900	Hardness (Ca, Mg) (mg/l)	630	20	109.5	2.35	89
1046	Iron (ug/l)	16200	< 50	781.1	6.58	108
625	Kjeldahl Nitrogen (mg/l)	--	--	--	--	--
1049	Lead (ug/l)	26000	3	208	4.89	108
1130	Lithium (ug/l)	600	100	126.2	1.63	38
925	Magnesium (mg/l)	105	1.9	20	2.56	108
1056	Manganese (ug/l)	800	50	75.4	1.82	108
38260	MBAS (mg/l)	--	--	--	--	--
71890	Mercury (ug/l)	< 10	< 1	2.43	2.49	108
1060	Molybdenum (ug/l)	200	< 50	100	1.25	20
1065	Nickel (ug/l)	< 100	< 1	< 23.2	2.28	71
71851	Nitrate (NO_3) (mg/l)	2	< 0.1	0.1	2.14	90
613	Nitrogen - Nitrite as N (mg/l)	0.60	< 0.20	0.07	3.93	37
631	Nitrite Plus Nitrate (N)(mg/l)	--	--	--	--	--
608	Nitrogen, Ammonia (mg/l)	3.2	0.40	1.18	1.77	18
607	Nitrogen, Organic (mg/l)	--	--	--	--	--
1330	Odor (severity)	--	--	--	--	--
550	Oil and Grease (mg/l)	--	--	--	--	--
	Organic Carbon (mg/l)					
681	Dissolved	73	3.0	10.5	1.58	100
689	Suspended	--	--	--	--	--
680	Total	--	--	--	--	--
	Pesticides (ug/l)					
400	pH*	8.9	6.0	7.16	0.48	107
32730	Phenols (mg/l)	1000	< 1	2.41	5.67	38
	Phosphate (mg/l)					
660	Dissolved (PO_4)	--	--	--	--	--
70507	Ortho (P)	1.00	< 0.10	0.11	1.44	106
665	Total (P)	--	--	--	--	--
935	Potassium (mg/l)	15.0	< 1.0	2.64	2.19	38
	Radioactivity					
1503	Gross Alpha (pc/l)	30.0	0.1	3.31	3.00	78
9503	Radium 226 (pc/l)	0.9	0.09	0.31	2.06	23
80030	Natural Uranium (ug/l)	--	--	--	--	--
3501	Gross Beta (pc/l)	830.0	2.0	21.4	3.13	38
80050	SR^{90} (pc/l)	--	--	--	--	--
3515	CE^{137} (pc/l)	--	--	--	--	--
1145	Selenium (ug/l)	< 100	< 10	< 10.2	1.25	108
955	Silica (SiO_2)	60.0	< 0.1	10.1	2.41	108
1075	Silver (ug/l)	100	< 1	8.9	1.40	66
930	Sodium (mg/l)	1560	155	397	2.12	108
931	Sodium Adsorption Ratio	--	--	--	--	--
540	Solids, Dissolved (mg/l)	3640	540	1075	1.97	108
1080	Strontium (ug/l)	3500-	200	680	2.21	20
945	Sulfate (mg/l)	580	< 4	112	3.40	108
746	Sulfide (mg/l)	6.50	< 0.01	0.56	3.97	38
11	Temperature (°F)*	75.2	46.9	58.5	3.57	106
1100	Tin (ug/l)	--	--	--	--	--
1150	Titanium (ug/l)	--	--	--	--	--
70	Turbidity (JTU).	--	--	--	--	--
1085	Vanadium (ug/l)	< 50.00	< 50.00	--	--	--
1090	Zinc (ug/l)	68000	20	239.2	3.80	106
1160	Zirconium (ug/l)	--	--	--	--	--

* Normal mean and standard deviation

A trilinear plot of all monitoring samples from the lower aquifer shows a concentrated clustering of points in the field where carbonate ions exceed 50 percent, i.e., $NaHCO_3$ water as shown on Figure 2.75. The field extends into an area where no one cation-anion pair exceeds 50 percent. This field represents mixing of the upper and lower aquifer.

Areal plots of Ca, Na, and TDS show relationships that a correlation analysis also supports, (see Figure 2.76, 2.77, and 2.78). TDS and Na have very similar areal distributions. Calcium, however, has a very distinct inverse Na and TDS. A correlation analysis indicates a direct relationship between Ca and SO_4. These constituents show inverse correlations to HCO_3, CO_3, Cl, F, and Na. This suggests that in areas where high TDS occur due to rock type or hydrological influences, Ca and SO_4 are removed, perhaps by precipitation.

Of the major chemical constituents, Ca, Mg, and SO_4 have on the average decreased over the two-year baseline period. Sodium, CL, HCO_3, K, and SiO_2 have shown a slight average increase as has TDS. Some constituent trends show linear increases, others indicate slight linear decreases; exponential trends also occur with time. Major chemical constituent correlation in the lower aquifer is similar to that in the upper aquifer (Figure 2.79). Again Ca, Mg, and SO_4 are inversely related to the rest of the major constituents and pH.

As with the upper aquifer, the same set of 27 chemical parameters from monitoring program samples were retained for the first factor analysis. Table 2.87 shows the factor loading matrix with associated eigenvalues and communalities. As can be seen, pH, conductance, TDS, Na, Cl, and F are generally all positively associated to a very high degree. Factor 2, which explains a smaller amount of the covariance than Factor 1, shows a high simultaneous direct correlation of calcium, magnesium, and sulfate with an inverse correlation with pH. This suggests solubility controls may be acting to restrict concentrations of these parameters. Factor 3 is dominantly loaded in the heavy metals.

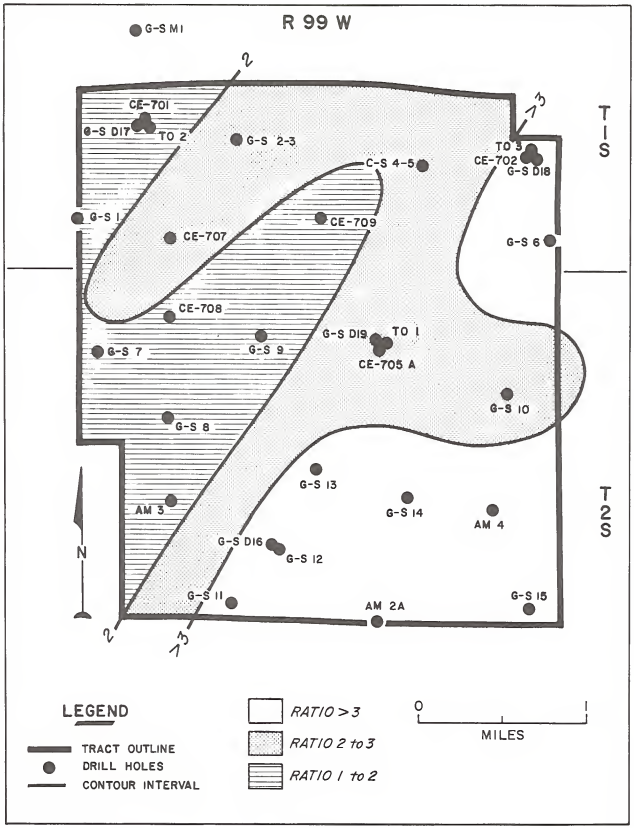


FIGURE 2.85

$HCO_3 + CO_3$ vs. $(HCO_3 + CO_3/pH)$ - LOWER AQUIFER

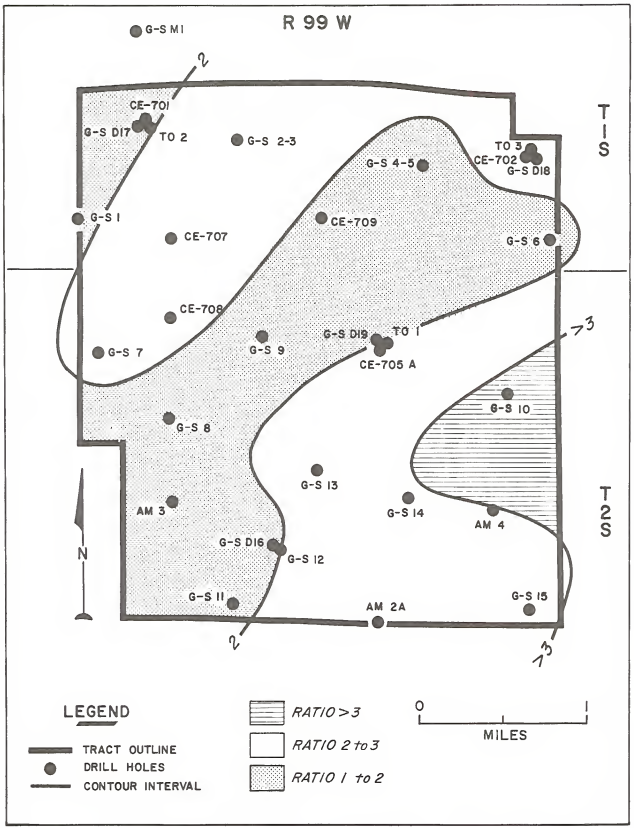


FIGURE 2.86
$HCO_3 + CO_3$ vs. ($HCO_3 + CO_3$/pH) UPPER AQUIFER

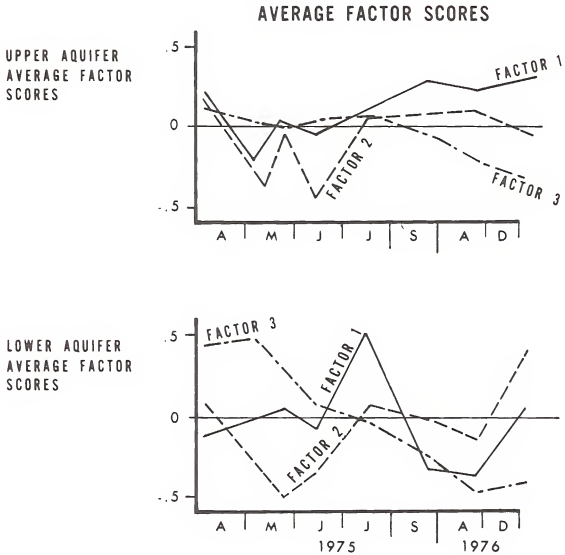


FIGURE 2.87

AVERAGE FACTOR SCORES FOR THE UPPER AND LOW AQUIFERS

Differences in pH values may be partially due to the different types of environments, oxidation, and reduction between alluvium and deep aquifer. The amount of SO_4 in alluvial water is believed to be to a large degree contributed from the deep aquifer system, perhaps from solution of gypsum in the upper aquifer.

A considerable amount of the combined explained variance among major water quality constituents over Tract C-a is due to results from CE-702 and G-S 6 in the northeast tract corner. Intercommunication of the aquifers in the area would account for the relatively high explained correlatable deviation from mean aquifer water constituent values. Factor scores from AM 3, G-S 12, and G-S 10 are high for both aquifers. AM 3 and G-S 12 are located along the Sulfur Creek anticline and this structure may account for changes in water quality, though analysis to date has not uncovered any substantial associated hydrological characteristics within the structure.

The lower aquifer was found to contain higher average concentrations than the upper aquifer of all analyzed constituents with the exception of the following (which occurred in lower concentrations by the following percents over the baseline period):

COD	27%
Hardness	66%
Calcium	75%
Magnesium	61%
Sulfate	65%
Silica Dioxide	61%
Manganese	42%
Molybdenum	23%
Silver	23%
Strontium	76%
Nitrate	24%

Solubility controls on the concentration of calcium appear to be operating in the upper and lower oil shale aquifers. This is suggested because of

the high inverse correlation between measured pH and calcium concentration. This is also suggested by the tight grouping of theoretical solubility constants plotted on Figures 2.88 and 2.89. The alluvial aquifer does not appear to be highly influenced by the same solubility controls. This difference in the alluvial aquifer may be due to the presence of near surface water that has percolated through soil with high carbon dioxide contents. This would tend to keep the solution under-saturated with respect to Ca if there were not sufficient sources of calcite for dissolution. Since the majority of the rock types present on tract are kerogen rich, dolomitic marlstones, this is not unexpected.

The statistical technique known as discriminant function analysis was used in order to statistically determine the most efficient chemical parameters for differentiating between water quality in the three aquifers. Discriminant function analysis transforms a standardized set of measurements on a sample into a single score; that is, a linear function of original variables. The coefficients of the discriminant function are mathematically selected so that maximum separation between previously defined groups is obtained. The standardized function coefficients are a measure of the importance of a particular variable in the differentiation between the groups.

A subset of the monitoring program water quality data was selected for the discriminant function analysis. Discriminator variables retained were as shown on Table 2.89 which lists the discriminant function coefficient for each of the variables. The results of this discriminant function analysis allowed 75 percent of the cases to be correctly classified; i.e. on the basis of the discriminant function equation, they were uniquely identifiable as to the source aquifer (Figures 2.90, 2.91, and 2.92). Figure 2.93 is a territorial map showing the relationship between discriminant function 1 and discriminant function 2 for waters from each of the three aquifers.

Map distributions of average discriminant functions score for the upper and lower aquifer were prepared and are shown on Figures 2.94 and 2.95. Discriminant functions score 1 in the lower aquifer generally ranges from minus 2 to minus 3. The lowest average score for discriminant function 1 occurs

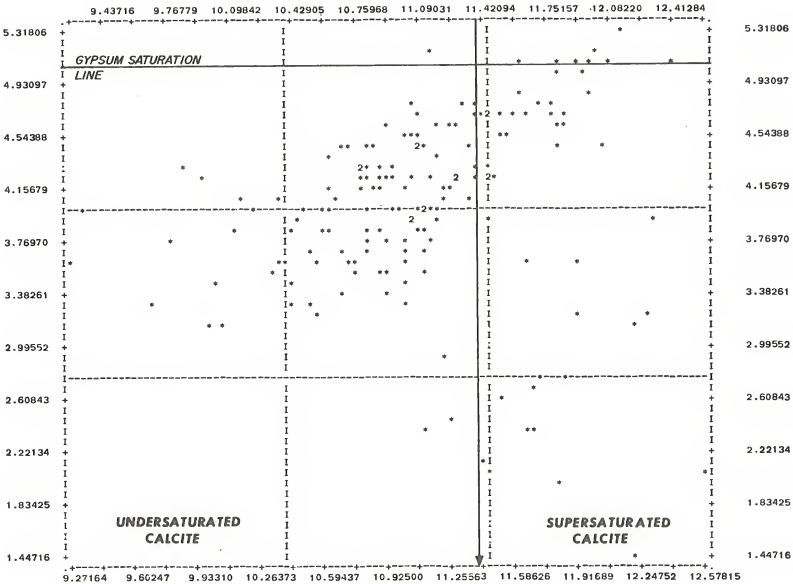


FIGURE 2.88

UPPER AQUIFER WATER QUALITY VS. CALCITE AND GYPSUM SATURATION FIELDS

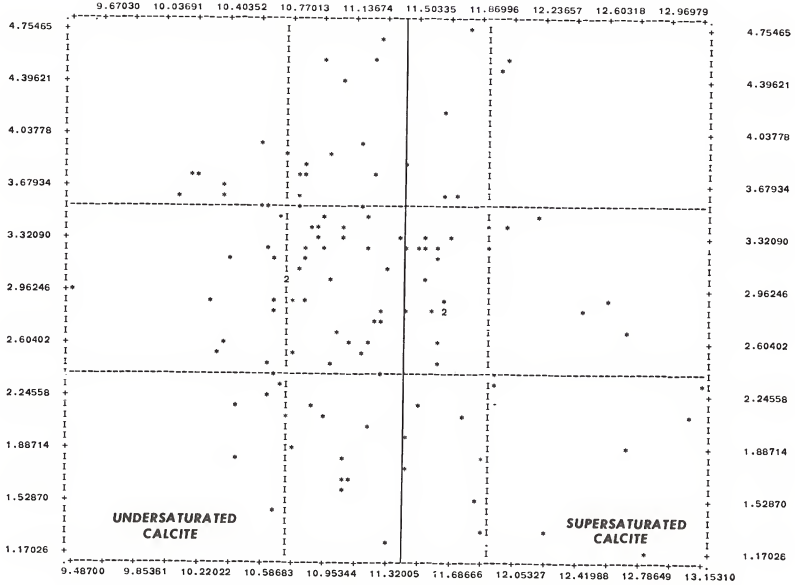


FIGURE 2.89

LOWER AQUIFER WATER QUALITY VS. CALCITE AND GYPSUM SATURATION FIELDS

TABLE 2.89

STANDARDIZED DISCRIMINANT FUNCTION COEFFICIENTS
FOR GROUND WATER MONITORING PROGRAM SAMPLES

	1	2
Conductivity	.39276	.09997
pH	- .15076	- .54949
Alkalinity	- .16271	1.02781
Calcium	.31226	.41636
Magnesium	- .00862	.26824
Sodium	- .54228	-1.26257
Chloride	.14495	.61852
Sulfate	- .06070	- .23525
Fluoride	- .78184	.90763
Silica	.58314	.44621

PLOT OF DISCRIMINANT SCORE 1 (HORIZONTAL) VS. DISCRIMINANT SCORE 2 (VERTICAL). * INDICATES GROUP CENTROID.

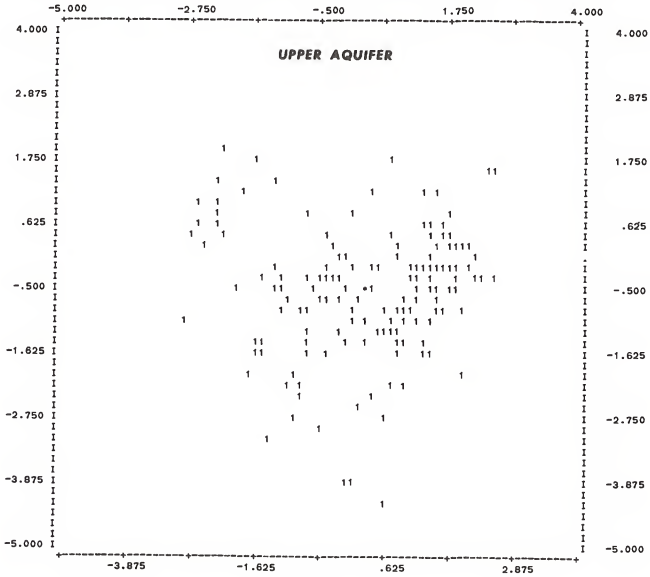


FIGURE 2.90
UPPER AQUIFER DISCRIMINANT SCORE PLOT

PLOT OF DISCRIMINANT SCORE 1 (HORIZONTAL) VS. DISCRIMINANT SCORE 2 (VERTICAL). * INDICATES GROUP CENTROID.

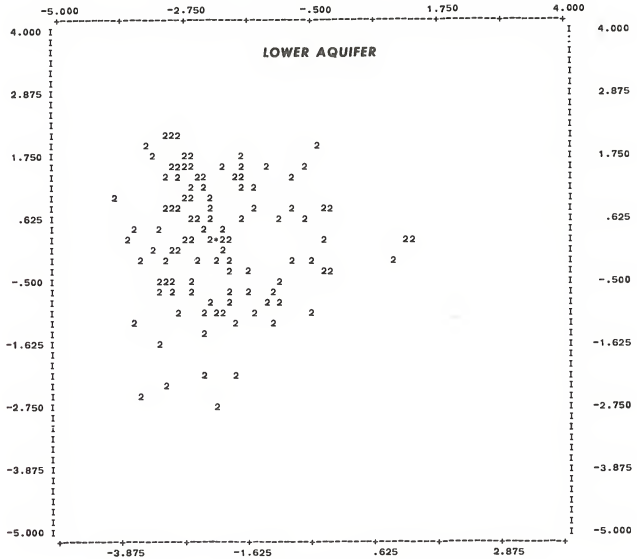


FIGURE 2.91

LOWER AQUIFER DISCRIMINANT SCORE PLOT

PLOT OF DISCRIMINANT SCORE 1 (HORIZONTAL) VS. DISCRIMINANT SCORE 2 (VERTICAL). * INDICATES GROUP CENTROID.

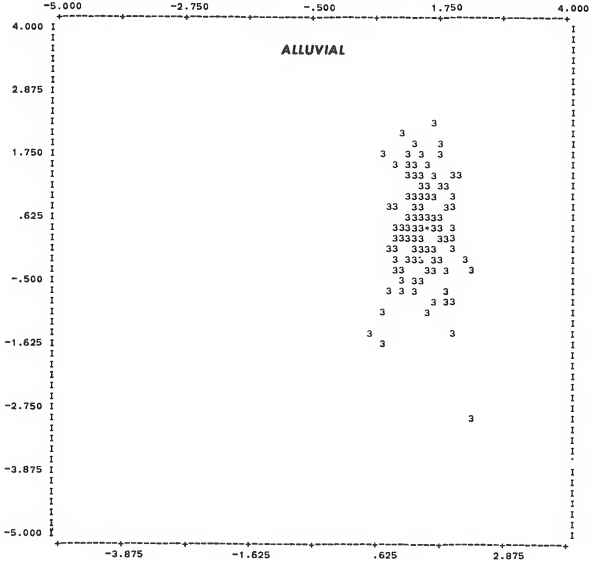


FIGURE 2.92

ALLUVIAL AQUIFER DISCRIMINANT SCORE PLOT

TERRITORIAL MAP OF DISCRIMINANT SCORE 1 (HORIZONTAL) VS. DISCRIMINANT SCORE 2 (VERTICAL). * INDICATES GROUP CENTROID.

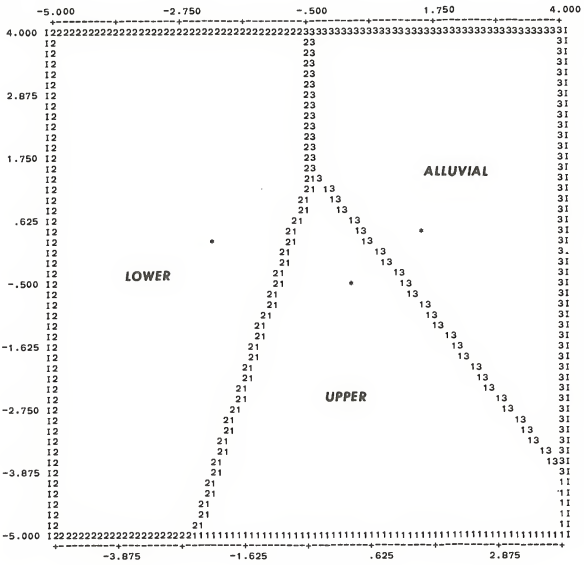
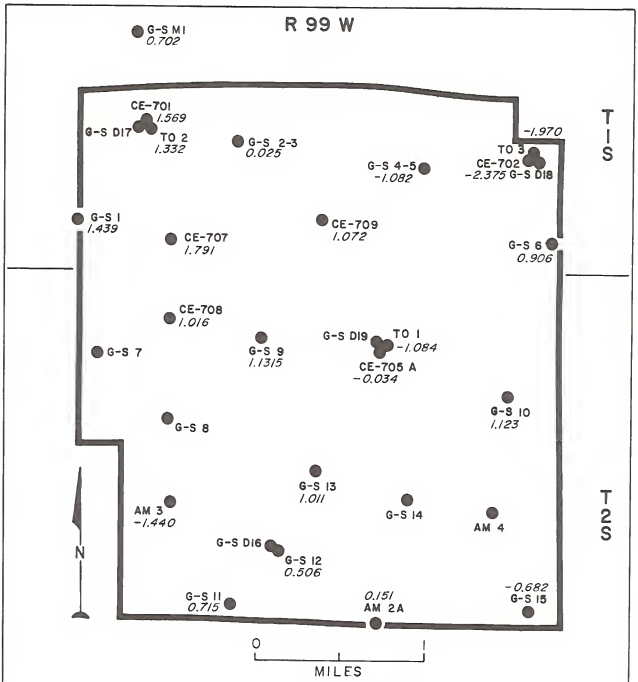


FIGURE 2.93

TERRITORIAL MAP OF ALL THREE AQUIFERS



LEGEND

TRACT OUTLINE
DRILL HOLES
CONTOUR INTERVAL

FIGURE 2.94
DISCRIMINANT SCORE 1,
AVERAGE FOR METHOD 1,
UPPER AQUIFER

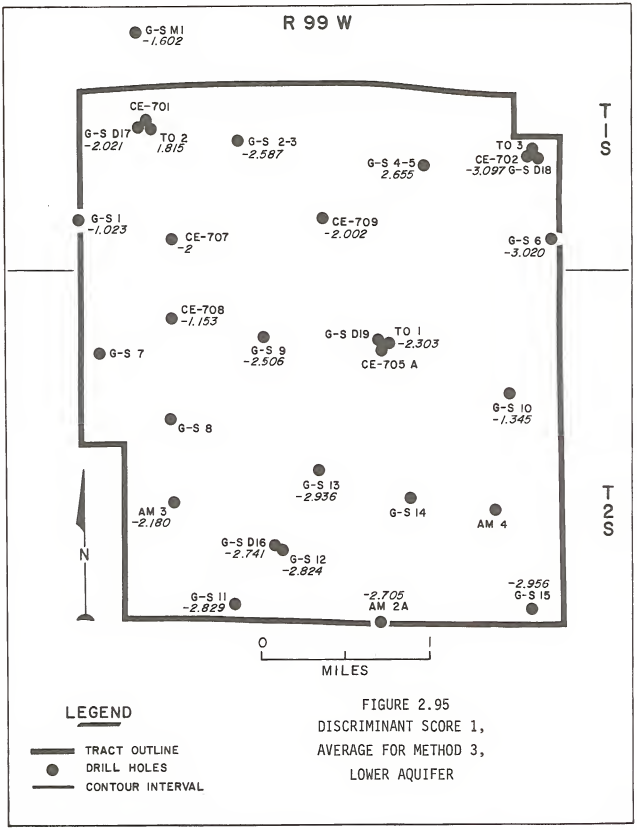


FIGURE 2.95
DISCRIMINANT SCORE 1,
AVERAGE FOR METHOD 3,
LOWER AQUIFER

In the northeast corner of the tract. Anomalously low values for the lower aquifer occur in those prelease core holes that remained open to the upper aquifer for some period of time before completion.

In addition, holes G-S 10, G-S M-1, and G-S 1 showed anomalously low values of discriminant score 1. Monitor hole G-S 1 is located in a fault zone so probable downward natural leakage of upper aquifer water tends to dilute low aquifer water. Possible leakage may account for the lower discriminant score at G-S M-1 and G-S 10. The map distribution for the discriminant score 1 in the upper aquifer generally shows positive values in a northwesterly trending central area and approximates most of the faulting on Tract C-a. High negative values approaching that in the lower aquifer are present in the northeastern corner of the tract suggesting an interconnection of the upper and lower aquifer in this region. The widespread nature of this similarity to low aquifer water quality type suggests that large scale natural processes are responsible. Water in Observation Hole CE 702 is not differentiable from lower aquifer water quality. Possible reasons for this obvious interconnection with the lower aquifer are:

- Abundance of natural faulting
- Possible poor sealing of one of the nearby exploration holes
- Possible interconnection by hydrological experiments conducted after drilling of CE 702

There is additional evidence that water quality observed in the monitoring holes for each of the individual deep oil shale aquifers was approaching that of a natural situation. Time trend plots of discriminant function score 1 were constructed for several of the holes. An example of one of these plots is shown on Figure 2.96 observation hole CE 707 lower aquifer. This hole remained open to the upper aquifer for approximately a year and a half and should have had its water quality type modified by mixing of the two aquifer waters. The trend plot shows that discriminant function score 1 has remained relatively stable over the past year, therefore, it is probable that water quality is now in an equilibrium situation.

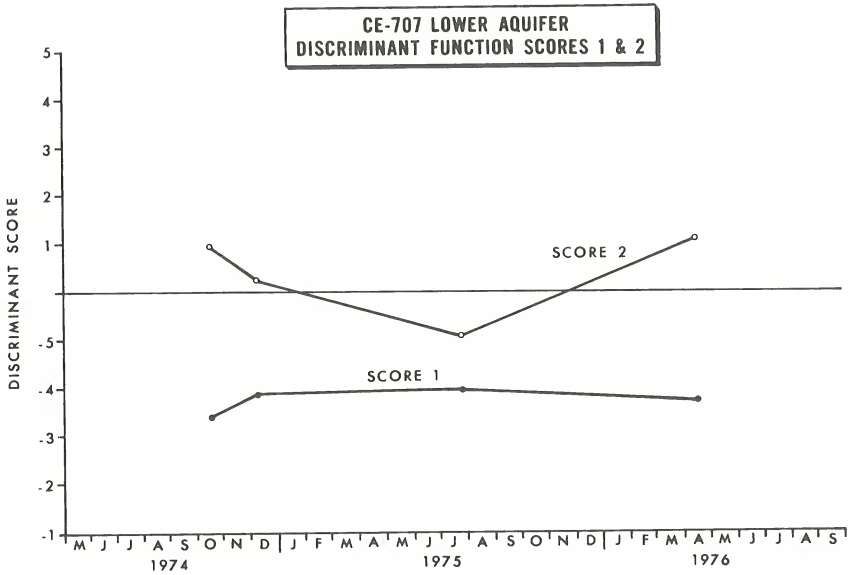
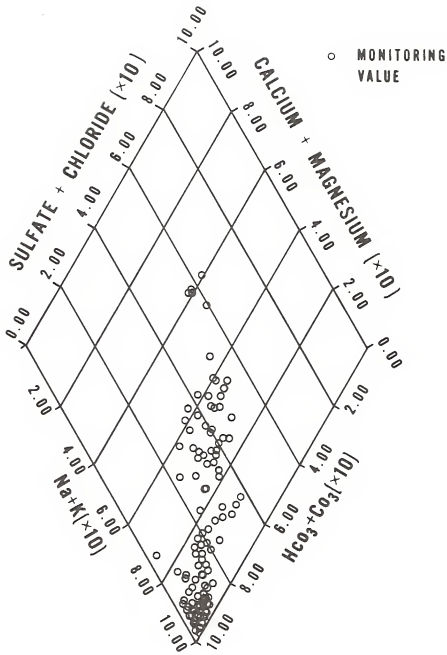


FIGURE 2.96

DISCRIMINANT FUNCTION SCORES 1 AND 2 FOR HOLE CE-707, LOWER AQUIFER



COMBINED LOWER AQUIFER TRILINEAR DIAGRAM

FIGURE 2.75

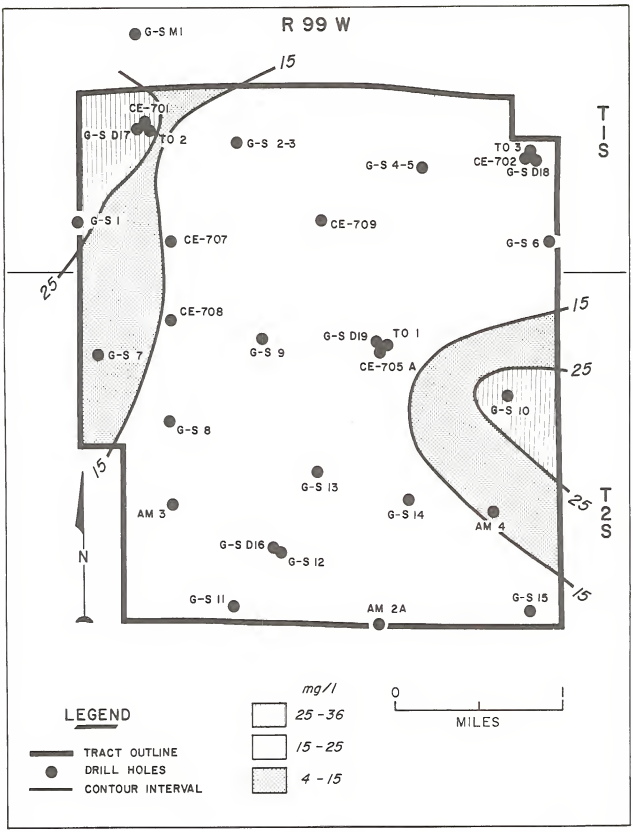


FIGURE 2.76
AREAL DISTRIBUTION OF CALCIUM, LOWER AQUIFER TRACT C-a

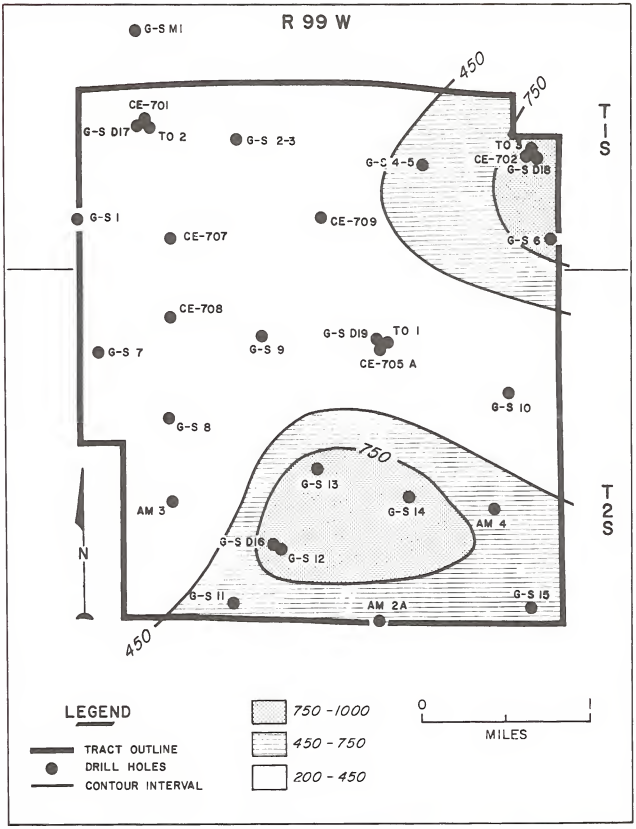


FIGURE 2.77
AREAL DISTRIBUTION OF SODIUM, LOWER AQUIFER TRACT C-a

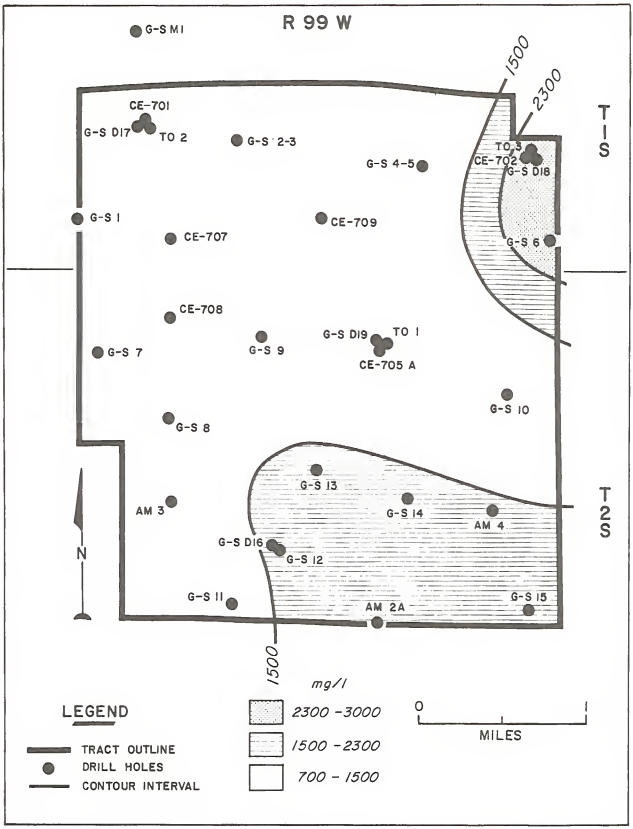


FIGURE 2.78

AREAL DISTRIBUTION OF TOTAL DISSOLVED SOLIDS LOWER AQUIFER, TRACT C-a

FIGURE 2.79

LOWER AQUIFER WATER QUALITY MONITORING PROGRAM SUMMARY

CORRELATION MATRIX

	Temperature	Conductivity	COD	pH	Alkalinity	Bicarbonate	Carbonate	TDS	Ammonia	Nitrite	Cyanide	Sulfide	Hardness	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Fluoride	Silica	Arsenic	Barium	Boron	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Molybdenum	Nickel	Silver	Strontium	Zinc	Aluminum	Lithium	Selenium	Gross Alpha	Gross Beta	Phenols	Phosphate	Ammonia	Nitrate	Bromide	Mercury
Temperature	+			+	+		+						-		-	+					+			+				+		-				-					+			+	+			
Conductivity		+	+	+	+	+	+	+				-	-	-	+	+	+	-	+	+				+		-				-		+			+		+		+			+	+			
COD						+					-															+								+		-	-								
pH	+	+	+	+	+	+	-					-	-	-	+		+	-	+				+	+				+			+		+	+	+	+	-	-		+		-	+	+		-	
Alkalinity			+		+	+	+					-	-	-	+	+	+	-	+	+			+							-	+	+								+			+	+			
Bicarbonate					+	+	+					-	-	-	+	+	+	-	+	+			+		-					-	+	+								+			+	+			
Carbonate					+		-		-	-	-	-	-	-	+		+	-	+	+			+				+	+	+			+	+	+	+	+	-			+			+			-	
TDS						+						-	-	-	+	+	+	-	+	+			+									+			+			+			+			+	+			
Ammonia-N											-		-		+	+		-		+			+		-													+			+						
Nitrite											+	+			+	+			+				+		-			-	-	-					-		+			-	+				+		
Cyanide																									+		-								-		+			-	+						
Sulfide																								+	+		-			+					-	-											
Hardness														+	+	-		-	+	-	-		-	-	+		+		+									+		-		+	+	-	-		+	
Calcium															+	-		-	+	-			-	-		-	+		+	-	-				-					-		-	-	-			+	
Magnesium																-		-	+	-	-		-	-	+		+		+		-	-	+								-		-	-				
Sodium																	+	+	-	+	+		+		-				-	+	+			+			+			+		+	+			-	
Potassium																				+			+		-		-	-	-							-	+			+			+			+	+
Chloride																		-	+	+			+								+			+	-	+			+		+	+		-	+	
Sulfate																			-	-			-	-				+	+	+		-										-	-				+
Fluoride																				+			+		-					-	+	+		-					+			+	+			-	
Silica																					-		-			-	-	-															+	+			
Arsenic																																												+		
Barium																																														
Boron																								+						-		+	+							+			+	+	+		
Cadmium																									+	-	+	-		+		+	+														
Chromium																										-												+							-		
Copper																											+			+			+	+													-
Iron																												+	+	-				+				+			+				+	-	+
Lead																												+		+	+	-	+					+				-		-	-		
Manganese																														-		-	+	+								-		-			
Molybdenum																																-															
Nickel																																+		+													+
Silver																																		+										-			+
Strontium																																				-									-		
Zinc																																				-	-		+		-	+				-	+
Aluminum																																													-	-	-
Lithium																																								+			+				
Selenium																																															
Gross Alpha																																										+	+				
Gross Beta																																															
Phenols																																													+		
Phosphate																																										+				+	
Ammonia																																														-	-
Nitrate																																															
Bromide																																															
Mercury																																															

+ is direct correlation significant at 5% level

- is inverse correlation significant at 5% level

TABLE 2.87

VARIMAX FACTOR LOADING MATRIX OF CHEMICAL DATA
FROM TRACT C-a LOWER AQUIFER MONITORING PROGRAM*

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Communality
Temperature	.33845			-.22556		.77974			.83265
Conductivity	.88440								.84406
pH	.60582	-.52061	.25539	.28771					.82557
Alkalinity	.81542	-.20680							.77602
TDS	.96906								.97382
Calcium	-.28142	.82668							.82467
Magnesium	.40838	.69160			.28156				.77313
Sodium	.93283	-.25692							.97578
Chloride	.82793						.20732		.77380
Sulfate	-.27149	.78647			.20525			-.24249	.80100
Fluoride	.71983	-.33241		-.39988			.20336		.87635
Silica	.46926			-.24375				.46195	.57187
Arsenic							.25630		.09308
Boron	.54206	-.25164	.41981		-.22108		.22294		.68043
Cadmium			.74010		-.25064				.68472
Chromium		.32349							.15233
Copper			.66551	-.20607					.52333
Iron		.28718	.36592	-.35033	.52787	-.30634	-.24459		.77443
Lead			.70966		.30876				.75983
Manganese					.77652				.64377
Nickel	.27710		.63173				.28275	-.24042	.73301
Zinc	.30085		.39132	.33152	.37298		-.20037		.56720
Selenium							-.22449		.06297
Gross Alpha	.62307	-.20907					-.25201		.56681
Phosphate	.42171	-.45738		.42569		.39842			.80637
NH4	.49256	-.28351	-.32799	-.43250					.64854
Nitrate							.43392	.46148	.41830
Mercury				.83523					.82305
Percent variance explained	46.2	15.9	11.0	9.0	7.0	5.1	3.2	2.6	
Cumulative percent	46.2	62.1	73.1	82.1	89.1	94.2	97.4	100.0	

*Loadings less than 0.2 omitted

A more limited subset of major chemical parameters was selected for analysis with subsequent areal plotting of factor scores. The results of this factor analysis are shown on Table 2.88. The communalities, or explained variances, were relatively high for all parameters retained in this analysis. Table 2.88 which explains most of the covariance shows simultaneous direct correlations between alkalinity, pH, TDS, Na, Cl, F and B. Factor 2 shows a high direct correlation between Ca, Mg, SO_4, with a moderate inverse correlation with the remainders of the parameters. Factor 3 is dominantly loaded in SiO_2 with minor correlations with the remainder of the parameters.

Figures 2.80, 2.81, and 2.82 show the map distribution of a mean factor score in the lower aquifer. Factor score 1 generally increases in a down-gradient direction in the lower aquifer with several anomolous points. Observation Hole CE-708 shows one of the lowest values, which is probably due to the open hole communication with the upper aquifer for a long period of time before hole completion. Map distribution for factor score 2 shown on Figure 2.81 shows that the high Ca, Mg, and SO_4 factor scores occur in a band on three sides of the tract. There appears to be a general trend in a northeasterly direction for decreasing factor score 2 in the down-gradient direction. This may possibly be due to increased dissolution of nahcolite with subsequent precipitation of calcite. Figure 2.83 shows the average factor score 2 for several holes in different structural settings over time. There is a general decrease in factor score two with time possibly due to diminishing of drilling effect.

Calcium and Cl and other constituent concentrations may be affected by generally northwest-southeast structure zones which cross the tract (Figure 2.84). Water quality zones of Ca and Cl appear to follow similar trends of most lower aquifer initial pumping test cones of depressions, fault structures, and the Sulfur Creek anticline axis.

A regular areal distribution, or correlation with other hydrological parameters, over Tract C-a of the major quality constituents Ca, Mg, SO_4, Cl, Na, and F was not clear in most cases. These constituents generally show pockets of high and

TABLE 2.88

VARIMAX FACTOR LOADING MATRIX OF CHEMICAL DATA
FROM TRACT C-a LOWER AQUIFER MONITORING PROGRAM*

	Factor 1	Factor 2	Factor 3	Communality
Alkalinity	.75114	-.34106	.30876	.77587
pH	.47725	-.46849	-.20813	.49057
TDS	.94711		.22388	.96108
Calcium	-.23957	.71385	.25265	.63081
Magnesium	-.25491	.79084	-.21126	.73504
Sodium	.86758	-.38412	.28881	.98367
Chloride	.65879			.44942
Sulfate		.84145	-.26874	.79053
Fluoride	.54170	-.48582	.38094	.67456
Silica	.28754		.65371	.51231
Boron	.53918	-.28447		.37857
Percent variance explained	74.0	17.6	8.5	
Cumulative percent	74.0	91.5	100.0	

*Loadings less than 0.2 omitted

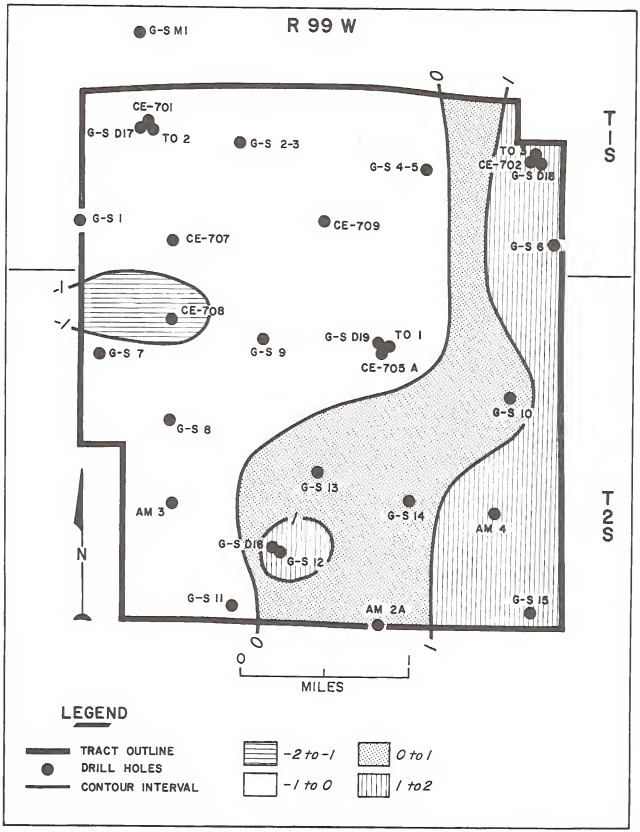


FIGURE 2.80

FACTOR 1-LOWER AQUIFER AREAL DISTRIBUTION

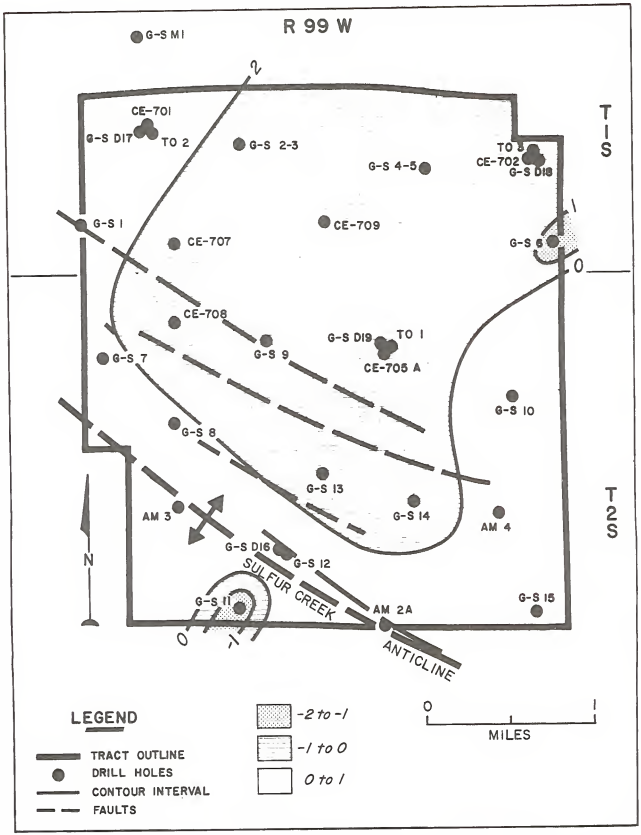


FIGURE 2.81

FACTOR 2-LOWER AQUIFER AREAL DISTRIBUTION

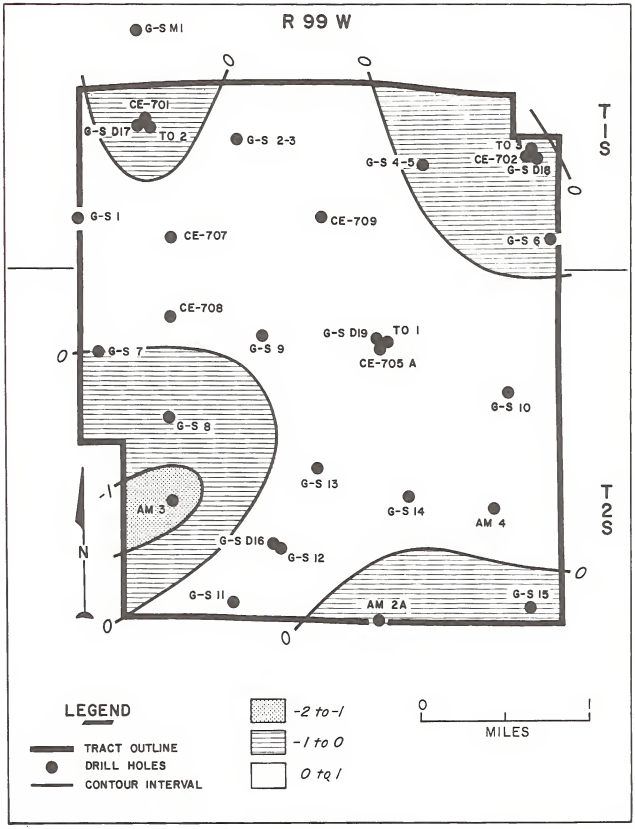


FIGURE 2.82
FACTOR 3-LOWER AQUIFER AREAL DISTRIBUTION

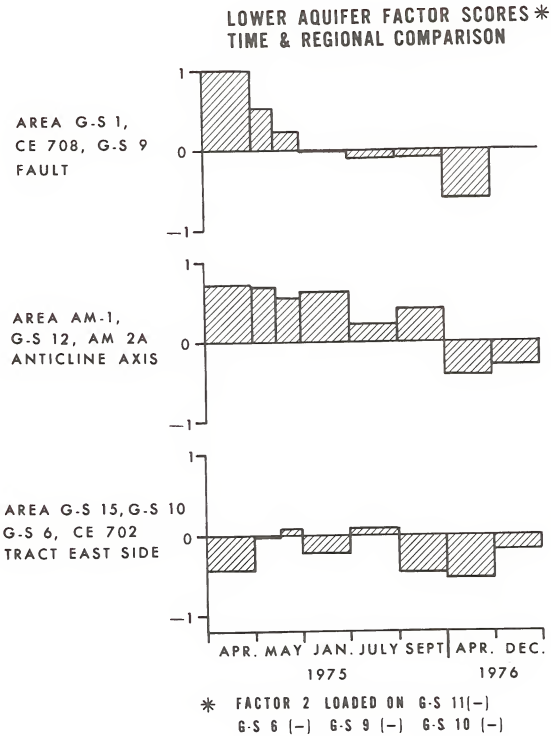


FIGURE 2.83
LOWER AQUIFER FACTOR SCORES

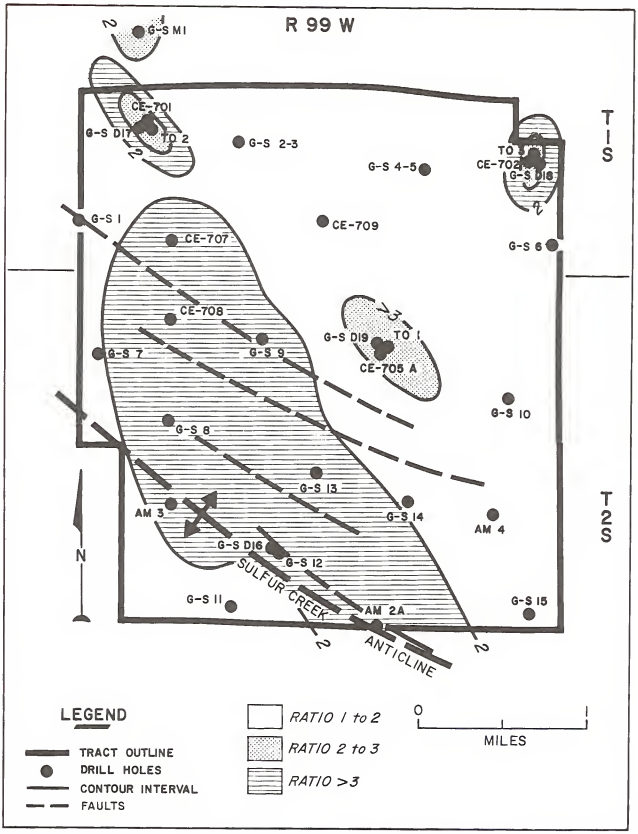


FIGURE 2.84

CHLORIDE RATIO-LOWER AQUIFER AREAL DISTRIBUTION

low concentration figures. It is assumed that local changes in structures, rock type, and aquifer permeabilities mask any regular trends in water quality that may be indicative of regional gradient trends.

IV. AQUIFER INTERRELATIONSHIPS

There are apparently no major changes in the ratios of pH to HCO_3 plus CO_3 equilibrium over the tract in both upper and lower aquifers, (Figures 2.85 and 2.86). The areal distribution of the (HCO_3 and CO_3)/pH ratio between aquifers shows a similar relationship. Very generally, there is an increase in HCO_3 and CO_3 eastward. This trend is interrupted in both deep oil shale aquifers by a trough of relatively low HCO_3 and CO_3 water concentrations whose surface axis follows Airplane Ridge Road.

By comparing the correlation of water constituents between the different aquifers, certain distinctions are apparent. Variation in water quality due to seasonal effects in the data may be a reason for some relationships. This appears to be the case in the upper aquifer where seasonal hydrograph effects are most apparent (Figure 2.51). Heavy metals show a more significant correlation with other constituents in the lower aquifer than in the upper aquifer. Gross beta and ammonia have a much greater variance in lower aquifer than in upper aquifer samples. As a result, a much better correlation exists for gross beta and ammonia upper aquifer samples. Nitrates in the alluvial combined correlation table show relatively better correlation when compared to deep aquifer nitrate correlations. This is probably due to organics from surface percolation into the alluvium.

Factor values of the upper and lower aquifers are compared over time on Figure 2.87. Factor values for TDS, Na, and SO_4 are the major factor values for the lower aquifer. The upper aquifer factor values are not as weighed toward so few constituents. Similarities and differences between aquifer factor values exist. Deep aquifer similarities based on factor values for particular constituents are noted. Some similarity with time exists for factor values for Na, Ca, SiO_2, and TDS. Some differences over time are noted for factor scores for TDS, SiO_2, and SO_4. Certain similarities of factor scores between upper aquifer and combined alluvium values are apparent. For the upper aquifer Mg and SO_4 values are similar to alluvial values.

Alluvial water quality was also considered in this discriminant function analysis in order to determine if it could be statistically separated from upper aquifer water quality type. Based on other methods of analyses, the alluvial and upper water qualities appeared to be very similar; however, fair differentiation based on the two discriminant functions was possible.

Tract C-a ground water quality as compared to suggested limits for drinking water quality and range animal consumption are shown on Tables 2.90 and 2.91. Calcium, Fe, Pb, Mg, Na, SO_4, TDS, and hardness have concentrations that may exceed drinking water quality limits. Calcium, F, and Pb concentration may be greater than suggested water quality limits for range animals.

CONCLUSIONS

There are three aquifer systems present in the subsurface on and around Tract C-a. These are the alluvial, and upper and lower oil shale aquifers. In general, TDS and the proportion of Na + HCO_3 increase with depth. Lower aquifer water quality is distinctly different from either of the other two aquifer systems due to the above parameters that increase with depth.

The alluvial aquifers are in hydrologic connection with the associated streams as was shown by the cyclical variation in water quality over the baseline period. The major constituents are directly correlated with each other with the exception of calcium and magnesium which are inversely correlated with the other major constituents. The oxidation potential in the alluvial aquifer varies seasonally with corresponding controls on heavy metal solubilities.

The upper aquifer is similar to the alluvial aquifer in water quality type with somewhat higher TDS. Interconnection of the upper and lower aquifers appears to exist in the northeast corner of the tract as the upper aquifer is similar in quality to the lower aquifer. No seasonal variation or time trends were found for the upper aquifer. Calcium, Mg, and SO_4 are generally inversely related to the rest of the major constituents and in addition, precipitation of $CaCO_3$ may be taking place.

TABLE 2.90

DRINKING WATER QUALITY LIMITS

COMPARED WITH TRACT C-a GROUND WATER QUALITY

	USPHS Limits	Alluvial Aquifer		Upper Aquifer		Lower Aquifer	
		Mean+	Probability[1] Limit Exceeded	Mean+	Probability[1] Limit Exceeded	Mean+	Probability[1] Limit Exceeded
Arsenic (mg/l)	0.05	< 0.01	0	0.01	45	0.01	0
Barium (mg/l)	1.00	< 1.0	0	< 1	0	< 1	0
Cadmium (mg/l)	0.01	0.017	75	0.009	45	0.009	45
Chloride (mg/l)	250	12.8	0	12.0	0	21.7	0
Chromium (mg/l)	0.05	0.01	0	< 0.01	0	< 0.01	0
Copper (mg/l)	1.00	0.01	0	0.073	40	0.09	0
Cyanide (mg/l)	0.20	0.01	0	0.01	0	0.01	0
Fluoride (mg/l	2.40	0.26	0	0.41	9	14.7	93
Iron (mg/l)	0.30	1.20	100	5.01	100	0.78	60
Lead (mg/l)	0.05	0.14	75	0.17	80	0.21	85
Manganese (mg/l)	0.05	0.57	88	0.13	85	0.07	75
Nitrate (mg/l)	45.0	3.9	0	0.21	0	0.16	0
Selenium (mg/l)	0.01	< 0.01	0	< 0.01	0	< 0.01	0
Silver (mg/l)	0.05	< 0.01	0	0.01	2	0.008	0
Sodium (mg/l)#	115	151.1	70	212	99	397	95
Sulfate (mg/l)	250	297	60	325	74	112	0
TDS (mg/l)	500	777	99	905	99	1075	85
Zinc (mg/l)	5.0	0.30	0	0.26	0	0.24	1
$Radium_{226}$ (pc/l)	3	0.26	0	0.17	0	0.31	0
$Strontium_{90}$(pc/l)	10	*	*	*	*	*	*
Hardness (mg/l)#	500	448	45	328	25	110	4

1 Percent of Times
+ Geometric Mean
# Unestablished limit
* Insufficient Data

TABLE 2.91

WATER QUALITY LIMITS FOR RANGE ANIMALS

COMPARED WITH TRACT C-a GROUND WATER QUALITY

	Limits[1]	Probability[+] Limit Exceeded		
		Alluvial Aquifer	Upper Aquifer	Lower Aquifer
Arsenic (mg/l)	0.15	0	0	0
Cadmium (mg/l)	0.01	75	45	45
Chromium (mg/l)	0.05	0	0	0
Fluoride (mg/l)	2.00	0	15	99
Lead (mg/l)	0.05	75	80	85
Selenium (mg/l)	0.01	0	0	0
TDS (mg/l)	10,000	0	0	0
Radium $_{226}$ (pc/l)	3	0	0	0
Strontium $_{90}$ (pc/l)	10	*	*	*

\+ Percent of Time

* Insufficient Data

1 McKee & Walt; 1963, Todd

The lower aquifer generally shows the highest concentration of TDS, Na and HCO_3. The origin of these high concentrations is the dissolution of nacholite and other saline minerals in the lower aquifer. The trend in concentration is toward an increase in the down-gradient direction. TDS has shown an increase over the baseline period due to recovery from downward leakage of low TDS water through open holes. Calcite precipitation may be taking place in the lower aquifer.

CHAPTER 7 - WATER RESOURCES AND AQUATIC BIOTA OF AREA

I. SURFACE WATER HYDROLOGY AND WATER QUALITY

The determination of the hydrologic baseline conditions was done through studies of precipitation, springs and seeps, surface water flow and quality, alluvial aquifers, and oil shale aquifers.

Data from the six rain gaging stations indicate a range of 10.7 to 17.2 inches of precipitation per year. The quantity of rainfall is generally related to elevation, with highest amounts occurring at the Cathedral Bluffs station, and the lowest quantities at the Yellow Creek Station. Tract C-a, based on the two years of available data, receives about 12 to 13 inches of precipitation annually.

Thirty-seven springs and seeps were inventoried in the Tract C-a area. More than 50 percent of the inventoried springs and seeps have shown perennial flows based on observations during the past two years.

All of the streams on Tract C-a are ephemeral or intermittent; however, some of the reaches are perennial. Data indicate that maximum stream flow and sediment discharge in the Tract C-a area occur during snowmelt runoff. Substantial differences in the quantity and character of the runoff on tract were detected between water years 1975 and 1976. The 1976 data showed lower runoff quantities and less intense snowmelt.

The two perennial stream reaches in the vicinity of Tract C-a are the result of springs. They are: in Corral Gulch near the western tract boundary which has about 0.18 cfs mean flow and in Box Elder Gulch where the minimum low flow coming from spring sources just west of Tract C-a is less than 0.1 cfs.

Both Corral Gulch and Box Elder Gulch generally have some flow leaving Tract C-a. Corral Gulch at the gaging station approximately 1/2 mile east of Tract C-a has an average flow of 0.73 cfs.

Duration curves for the four stations with continuously monitored hydrologic parameters were plotted. These plots allow evaluation of the probability of exceeding given values of each of the hydrologic parameters at each of the four stations. In order to evaluate how well the baseline period represents long-term variations in hydrologic characteristics, a comparison of deviations of yearly flow from mean flow were made for Piceance Creek and several stations on the White River. The analysis showed that water year 1975 had above normal flow and water year 1976 had below normal flow.

The important constituent to note is the total dissolved solids, which is an indicator of overall water quality. In the vicinity of the tract, surface water quality is quite good, having an average dissolved solids content of about 820 mg/l in Corral Gulch where it leaves the tract. Surface water quality near Tract C-a was compared with quality standards for drinking water and range animal use. Dissolved solids and sulfate exceed the drinking water limits more than 50 percent of the time. Data indicate that some natural water quality deterioration takes place across Tract C-a due to interaction of surface water with the alluvium. Yellow Creek near its confluence with the White River has an average dissolved solids content of $\sim$ 2,500 mg/l. At this site, USPHS drinking water standards for sodium, sulfate, and dissolved solids are exceeded 100 percent of the time and fluoride 30 percent of the time. Yellow Creek exceeds standards for fluoride for range animal use 23 percent of the time.

The general water quality type for surface water was investigated using trilinear diagrams. This analysis showed that the major constituents of the surface waters were tightly grouped. Tract C-a surface water quality are similar to quality of springs while Yellow Creek appears to be a mixture of upper and lower aquifer water types.

Interrelationships between chemical parameter concentrations were examined and several important conclusions were developed and confirmed with the results of factor analysis. Sodium and bicarbonate are the dominant ions present in Tract C-a surface waters and are directly associated with total dissolved solids content and specific conductance. A secondary association between

parameters occurred between calcium, magnesium, and sulfate, whereas these parameters as a group tended to be independent of sodium and bicarbonate. Some solubility controls may be acting on calcium concentrations as shown by the moderate inverse correlation between pH and calcium.

II. AQUATIC BIOLOGY

During the two-year RBOSP Aquatic Baseline Studies, five major aquatic habitat types were identified among the 35 sampling stations located on or near Tract C-a. The habitats included small, shallow spring brooks; small shallow ponds; Yellow Creek; White River back channel habitats; and White River open channel habitats.

The spring brooks were generally less than 0.3 m (1 foot) wide and less than 2.8 cm (1 inch) deep. Substrates in these habitats were generally loose aggregations of sand, gravel, and shale pieces covered with periphyton.

Three of the sampling stations were characterized as ponds: two (Stations 5 and 19) were weed-choked seepage areas and the other (Station 14) was a pond during the 1974-1975 sampling period and, although it was subjected to a natural wash-out and accumulation of sand and silt, it was considered a pond again during 1976.

Yellow Creek, near its confluence with the White River, is a small perennial highly-alkaline spring brook. The substrate of this habitat consists of sand and gravel, although silt and detritus compose a considerable portion of the substrate at times.

Back channel habitats in the White River included Stations 23, 27-29, and 33. These habitats are located in back channel areas where water velocities are somewhat less (0.2 - 5.8 ft/sec) than in the main channel (0.6 - 7.5 ft/sec). Substrates in these habitats are heterogeneous, but a major portion of all these substrates is cobble with rubble and gravel. During periods of low flow, heavy silting is observed in these habitats.

The main, or open channel habitats in the White River included Stations 24-26, 30-32, 34, and 35. These habitats are located in areas of swift water velocities. Substrates in these areas are heterogeneous. Near the middle of the river, large cobbles and boulders are found; at the edge of the river, cobbles and gravel are most common. During periods of low flow; sand, silt, and some detritus are deposited in areas of low velocity.

All waters in the RBOSP study area were very alkaline (pH 7.3 to 8.7); Yellow Creek was the most alkaline (pH 8 to 10.1). The relatively soluble substrates of the drainage area provide high concentrations of dissolved materials. Waters in the study area ranged from hard to very hard and contained both carbonate and non-carbonate hardness. In Yellow Creek, magnesium was found in higher concentrations than calcium (mean of 108 mg/l vs 31.8 mg/l, respectively) the reverse of that found in most waters. The concentration of dissolved solids was high in all areas, and particularly so in Yellow Creek (1,740 to 2,870 mg/l). Suspended solids were generally highest in the waters on or near Tract C-a. Waters of the tract area and of Yellow Creek contained the greatest quantities of organic matter (dissolved organic carbon ranged from < 1 mg/l to 67 mg/l) due to greater contributions of allochthonous organic material from nearby plant communities and grazing livestock. Inorganic plant nutrients, particularly nitrogen (total nitrogen ranged from < 0.1 mg/l to 8.5 mg/l) and phosphorous (total phosphate ranged from 0.01 mg/l to 5.4 mg/l) were generally found in concentrations which would not limit the growth of algae, and were often found in concentrations considered enriching. Yellow Creek usually contained the most unusual and the hardest chemical conditions of all the aquatic habitats included in the RBOSP Aquatic Baseline Studies.

In all ecosystems, the three principal kinds of organisms (decomposers, consumers, and producers), are trophically interdependent. In many rivers and streams, primary production is, to a large degree, derived from terrestrial vegetation outside the aquatic ecosystem (allochthonous) Allochthonous detritus is of great importance in many streams, where a majority of animals at the second trophic level are detritus-feeders. In other streams, however, periphyton or the benthic algal community is the

most important source of fixed energy, and herbivores comprise a majority of animals at the second trophic level. However, as the periphyton community contains detritus (allochthonous and autochthonous) mixed with algae, protozoa, etc. the distinction between herbivorous and detritivorous secondary consumption is not easy to quantify. Thus, virtually all flowing waters have secondary trophic levels (benthic and a few planktonic invertebrates and some fish) that are both herbivores and detritivores. Higher trophic levels are mostly composed of fish.

The major source of autochthonous primary production in waters of the study area is periphyton. Phytoplankton constitutes a minor source of primary production in these habitats. Secondary trophic levels (primary consumers) in the aquatic habitats are primarily benthic macroinvertebrates, although some planktonic invertebrates do occur. In the White River, some fish also fill secondary trophic levels (primary consumers). Fish of the White River are either primary, secondary, tertiary, or quarternary consumers, depending upon the organisms which they ingest. This results from the feeding habits of the aquatic insects of this area. Ephemeroptera are primarily herbivorous, Odonata and some Chironomidae are carnivorous, the Plecoptera are omnivorous and others are detritivorous.

In the alkaline spring brook habitats on and near Tract C-a, phytoplankton constitutes a minor source of autochthonous primary production. Phytoplankton densities in these habitats are generally low (ranging from 628 to 9,039 cells/ml) observed during the late Spring and late Summer and lowest densities observed in July. The predominant taxa were diatoms. The commonality of species composition and of predominant species in the phytoplankton and periphyton of these habitats indicates that the planktonic algae is generally derived from periphytic algae.

The zooplankton fauna of these habitats were mostly littoral taxa. Macrophytes were rare or absent, and their absence probably accounts for the low abundance of littoral Rotifera and Cladocera (925 to 24,067 organisms/m^3 and 447 to 3,804 organisms/m^3, respectively). Protozoan populations were dominated by Centropyxis constricta and peritrich ciliates. Rotifers

occurred in highest densities in June of each year and were dominated by bdelloids and monogononts. The crustacean fauna of these habitats was composed almost entirely of benthic ostracods and harpacticoids and their nauplii. No seasonal trends were observed for crustaceans. As with the phytoplankton, the zooplankton of the spring brook habitats were largely derived from benthic sources, and are thus generally not a major functional component of the aquatic communities of this habitat type.

Periphytic algae constituted the major source of autochthonous primary production and macrophytes were rare or absent in the spring brooks. Diatoms were the predominant periphyton taxa. Greatest periphyton standing crops in these habitats were observed in the early Winter of both years (8,856 cells/mm^2 in 1974 and 26,974 cells/mm^2 in 1975). Maximum Shannon diversity indices occurred during July of each year (2.16 in 1975 and 1.86 in 1976), whereas the lowest indices (1.29 in 1975 and 1.53 in 1976) were observed in the early Spring of each year when cell densities were only moderately high. Shannon indices were generally lower in the spring brooks than in other habitat types, indicating that the periphyton communities of the spring brooks were less complex than those in the more permanent waters of the region. This may be attributed to the limited habitat complexity and availability of a diverse upstream seed source.

The benthic fauna of the spring brooks in the headwater areas west of Tract C-a included the segmented worm families Naidiadae and Enchytraeidae, and aquatic insects (Diptera, Ephemeroptera). The aquatic insects which occur in these spring brooks have univoltine (one generation/year) or multivoltine (more than one generation/year) life cycles. Aquatic insects which require two or three years for development have not been successful in invading these headwaters. The remaining spring brook habitats are more ephemeral in nature, favoring those species which can easily invade new waters by various means (drifting, active upstream movement) or which can burrow into hyporheic zones during periods of drought. As in the headwaters, the benthic fauna of these habitats were dominated by the Diptera, Ephemeroptera, and Oligochaeta.

In the pond habitats on and near Tract C-a, phytoplankton densities were lower (mean densities from 138 to 3,555 cells/ml) than in any other habitats, except the White River open channel areas. These consistently low densities were likely due to reduced scouring of the periphyton in the ponds and the reduced flows which permitted the suspended benthic algae to settle. As in the other habitats, phytoplankton was dominated by diatoms and constituted a minor source of autochthonous primary production.

Zooplankton was generally more abundant in the pond habitats (mean densities from 2,952 to 160,797 organisms/m^3) than in the spring brooks (2,991 to 39,432 organisms/m^3). Rotifers were often the major components of pond zooplankton (1,567 to 158,633 organisms/m^3), and were most abundant in Summer. The crustacean fauna in these habitats was usually abundant and diverse. The species observed were generally typical of North America pond habitats. Maximum densities of crustaceans (4,820 organisms/m^3 in 1975 and 51,085 organisms/m^3 in 1976) occurred in Summer of both years. As in the spring brooks, temperature was apparently an important limiting factor in controlling the distribution and abundance of zooplankton in these habitats.

In the ponds, aquatic macrophytes contribute a greater portion of the autochthonous primary production than in the spring brooks. Much of this plant material is not used by primary consumers, since, according to Cummins (1974), rooted aquatic macrophytes are subject to little grazing except at times of dieback. Periphyton is thus the major source of utilized autochthonous primary production in the ponds. Periphyton communities of the ponds were more diverse than those of the spring brooks, as indicated by a generally higher number of species observed and higher Shannon diversity (pond diversities ranged from 1.79 to 2.99). Periphyton abundance was greatest during early winter of each year (15,907 cells/mm^2 in 1974 and 14,645 cells/mm^2 in 1975). Cell densities were slightly higher during the first year of study. Diatoms were the most dominant periphyton taxa.

The major components of the benthos communities of the ponds were dipterans (Chironomidae, Simuliidae, and at times, Ceratopogonidae), Oligochaeta, and Callibaetis. Macroinvertebrate abundance and Shannon diversity were high in the ponds throughout the study period (total abundance ranged from 7,601 to 85,874 organisms/m^2; Shannon diversities ranged from 1.54 to 3.81).

The benthos communities of the pond and marshy habitats differed from those of the spring brooks. At Station 5, decaying aquatic vegetation provided a greater food supply than in spring brooks and the favorable substrates and higher dissolved solids concentrations resulted in diverse and dense populations of invertebrates. Tubificidae, Chironomidae, Ephemeroptera, Simuliidae, Hydroptila and Grammotaulius were abundant or common at Station 5.

In Yellow Creek, the high levels of dissolved constituents limit the types of organisms which can exist. Phytoplankton densities (mean densities of 557 to 22,331 cells/ml) were generally higher in Yellow Creek than in any of the other habitats; these higher densities are related to the greater number of sources of recruitment of periphytic algae, as well as the different physical and chemical conditions in Yellow Creek. Phytoplankton maxima (9,875 cells/ml in 1975 and 22,331 cells/ml in 1976) occurred in the Spring of both years in this habitat.

The benthos communities of the pond and marshy habitats differed from those of the spring brooks. At Station 5, the increased food supply (from decaying aquatic vegetation), the substrate and higher dissolved solids concentrations contributed to the increased number of species and individuals which occurred here. At Station 5, Tubificidae, Chironomidae, Ephemeroptera, Simuliidae, Hydroptila and Grammotaulius were abundant or common.

In Yellow Creek, the high levels of dissolved solids and the generally harsh chemical conditions limit the types of organisms which can exist. Phytoplankton densities (mean densities of 557 to 22,331 cells/ml) were generally higher in Yellow Creek than in any of the other habitats; these

higher densities are related to the greater number of sources of recruitment of periphytic algae, as well as the different physical and chemical conditions in Yellow Creek. The phytoplankton maxima (9,875 cells/ml in 1975 and 22,331 cells/ml in 1976) occurred in the Spring of both years in this habitat. Diatoms were the dominant taxa in the phytoplankton during the study. Phytoplankton abundance in Yellow Creek was generally higher during the second year of study. As in the other habitats, phytoplankton in Yellow Creek, played a secondary role in autochthonous primary production and were generally derived from periphytic algae.

The zooplankton species composition in Yellow Creek was generally similar to that observed in the pond habitats. As in the spring brooks and ponds, highest densities (11,228 organisms/m^3 in 1975 and 20,783 organisms/m^3 in 1976) occurred in Summer and early Fall. Rhizopods dominated the Protozoa, whereas the crustacean fauna of Yellow Creek was generally similar to that of the ponds. The Rotifer fauna of alkaline waters, and several of the species present (Notholca acuminata, Notholca squamula, and Colurella adriatica) are considered tolerant of brackish water (Remane and Schlieper, 1971). Ostracods were the dominant crustacean forms. The zooplankton fauna of Yellow Creek can serve as food for many of the filter-feeding or predaceous cyclopoid copepods was related to increased abundance of their food, i.e., the rotifers and cladcerans, during the Summer.

In Yellow Creek, macrophytes were rare or absent. Thus the periphytic algae constituted the major source of autochthonous primary production in this habitat. Diatoms were the dominant algal taxa in the Yellow Creek periphyton. Periphyton densities were greatest in October of both years (14,511 cells mm^2 in 1974 and 12,547 cells/mm^2 in 1975) whereas the highest organic weights (0.2143 and 0.2093 g/50 cm^2) were observed during June of each year. The higher organic weights observed during June are probably due to the occurrence of species of larger diatoms. Periphyton diversities (Shannon indices) were higher in Yellow Creek (range of 0.76 to 2.77) than in the spring brooks and ponds but lower than in the White River.

The benthic faunal diversity in Yellow Creek is limited by the severe chemical conditions which exist in that habitat. Those species which can tolerate the harsh conditions, particularly the Simuliidae and Chironomidae, occur in great abundance. The average number of taxa in Yellow Creek was lower than in other habitats, except in the ephemeral spring brooks. Approximately 60 percent of the fauna composition of Yellow Creek was composed of Chironomidae, Simuliidae, and Ceratopogonidae.

In the White River two habitats (back channel and open channel) were identified during RBOSP Aquatic Baseline Studies. The phytoplankton species composition and abundance was very similar in these two habitat types. This similarity was due to the paucity of slackwater areas and to the swift currents which reduce the ability of truly planktonic species to develop. Phytoplankton maxima were observed in both open and back channel habitats in the Winter and Spring. The phytoplankton of the White River contained a mixture of algae derived from both periphytic and truly planktonic sources Diatoms dominated the phytoplankton in the White River, but the composition and abundance differed from those observed in the other habitats. In general, phytoplankton abundance was low (mean densities from 401 to 2,150 cells/ml) in the White River and the phytoplankton were derived primarily from benthic sources.

Zooplankton species composition and abundance were similar in the open and back channel habitats. Protozoa were dominated by Centropyxis spp. and peritrich ciliates, but no seasonal trends were evident. Rotifers were less abundant in the White River than in other habitats but the species composition was similar to that observed in the other habitats.

Rotifer densities were generally highest during the Summer (mean densities of 638 to 7,075 organisms/m^3). The crustacean fauna was extremely sparse and was composed primarily of copepod nauplii. Protozoa was a much larger component of the river fauna than other habitats and mean densities were also slightly higher in the White River. These trends are related to the abundance of rhizopods whose presence in the plankton is partially controlled by substrate disturbances and the velocity of the stream. The

distribution and abundance of Cladocera and Cyclopoida paralleled those of the Rotifera. The absence of macrophytes and the high stream velocities in the White River limited their distribution and abundance. The low densities of zooplankton (mean densities of 3,607 to 23,444 organisms/m^3) preclude its having major significance as a food source.

The major source of autochthonous primary production in the White River was the periphytic algae. Diatoms were the predominant algal taxa. The species composition, organic weights, and abundance of periphyton in the White River were similar in back channel and open channel habitats. Greatest densities (31,228 cells/ml in 1975 and 11,966 cells/ml in 1976) were observed during the late Summer and Fall of 1975 and Spring of 1976. Shannon diversity indices, number of species (range of 2.11 to 3.61) and evenness were generally higher in the White River than in any of the other habitats. The factors which account for the higher standing crops and diversities in the White River included greater current velocities, more suitable substrates, less severe chemical conditions, and a greater availability of seed material than in the other habitats.

The White River is characterized by a rubble substrate which provides many interstitial spaces for benthic habitat. Although the benthic community of the White River was more diverse (Shannon diversities ranged from 1.05 to 4.04) than that of any other habitat, densities of macroinvertebrates were lower in the White River (210 to 5,476 organisms/m^2) than in Yellow Creek. Shannon diversity indices for the open channel areas (range of 1.05 to 3.98) were generally higher than those for the back channel (range of 1.29 to 4.04). This may be attributed to the difference in substrates since the open channel substrate consists of boulders mixed with cobbles and rubble, whereas the back channels are heavily silted at times. The benthic community of the back channel habitats are dominated by Ephemoroptera, Trichoptera (Hydropsyche) and Oligochaeta, while the open channel habitats were dominated by Chironomidae, Oligochaeta, and Simuliidae.

During the RBOSP Aquatic Baseline Studies, 15 species of fish representing five families and one hybrid were observed in the White River and in the

lower reaches of Yellow Creek. The most abundant species were, in descending numbers; speckled dace (825 fish in 1974-75; 793 fish in 1975-76), flannelmouth sucker (523 fish in 1974-75; 408 fish in 1975-76), mottled sculpin (413 fish in 1974-75 and 415 fish in 1975-76), fathead minnow (309 fish in 1974-75 and 57 fish in 1975-76), and bluehead sucker (159 fish in 1974-75 and 115 fish in 1975-76). The composition of the fish catch was similar during both years of study except that numbers of fathead minnows were lower during the second year. Four species (cutthroat and rainbow trout, mountain sucker, and black bullhead) were captured only rarely and only during the first year. No threatendd or endangered species were observed during the two-year baseline study.

The dominant "large fish" of the RBOSP study area, the flannelmouth and bluehead suckers, were caught in similar proportions in both years of study; the flannelmouth was approximately 3.5 times more abundant than the bluehead sucker.

During the two-year baseline study fish catches generally fell into three general categories: small catches at Yellow Creek Stations 20, 21,and 22; intermediate catches at the main channel White River Stations; and large catches at the back channel White River Stations. Mean numbers of species and weights per collection were highest in the back channels. The larger catches in the back channels were related to more effective fishing in those slow-water areas, especially when they were blocked off, and to the possible congregation of fishes in these areas.

In general, the composition of fish catches by habitat was similar during both years of study. Yellow Creek produced a few fish whereas the White River back channel stations produced the largest catches. The high catches in the White River were due to a combination of greater sampling efficiency and possible congregation of fishes in these areas. Yellow Creek is reduced to a series of warm-water pools during much of the year and the low catches are related to the small amount of habitat available.

Oxygen concentrations in the White River were never far below saturation during the study period. Water temperature is another environmental factor

that influences the presence or absence of fish species. On the basis of water temperature, the White River study area could be characterized as a "cool water" habitat. The mottled sculpin, which is abundant in the area, is said by Beckman (1952) and Miller (1964) to prefer cool to cold mountain streams. The various trout and the mountain whitefish, which also occur at the site in low numbers, are cold-water species. However, the presence of other species commonly associated with warm water habitats (carp, channel catfish, red shiner and, presumably, flannelmouth sucker) suggest intermediacy of habitat with regard to temperature.

It appears that the optimum water temperatures for trout are exceeded in some years. Maximum summer water temperatures of the White River in 1973 and 1975 were 15.3 C (Pennak, 1974) and 22 C (present study). These temperatures are within the preferred ranges of rainbow and brown trout (McAfee 1966; Scott and Crossman 1973). However, a temperature of 24 C was reported for the White River near the RBOSP site in Summer, 1969 (Everhart and May 1973). This was in excess of the upper preferred temperature of rainbow trout and at the upper preferred limit of brown trout. Therefore, the low numbers of salmonids at the site may be due, at least in part, to above-optimum summer water temperatures in some years.

Although dissolved solid concentrations are high in the White River (205 - 1,041 mg/l) and very high in Yellow Creek (1,740 - 2,870 mg/l), the levels are not high enough to be deleterious to fish. McKee and Wolf (1963) reported that the limiting concentrations of dissolved solids for survival of freshwater fish are probably in the range of 3,000 - 10,000 mg/l, well in excess of the maximum values recorded for the study area. Of the ionic constituents of dissolved solids, only sodium occurred at levels that are possibley detrimental to fish. Some fish mortality has been experienced at sodium levels of 500 - 1,000 mg/l (McKee and Wolf 1963). However, the highest level of sodium (977 mg/l) and other dissolved solids was recorded in lower Yellow Creek in May and June 1975 at a time when large numbers of fish were present, apparently unaffected by the relatively high concentrations of dissolved solids.

Hynes (1970) pointed out the importance of shelter to fish. For example trout are more abundant where there are more sheltered areas. In the RBOSP study area, long stretches of the White River have little suitable shelter such as large rocks, boulders, or logs. What shelter exists is in the

back channel areas; the nine trout captured to date were taken in back channel areas. The lack of shelter may contribute to the low numbers of trout in the study area.

The waters of the White River carry a high silt load (peak in April during the present RBOSP study) that is apparently due to high alkalinities and clay content of the streamside soils in the area. The substrate in the main channel areas of the river is free of silt, but slowflowing backwater areas have deep silt deposits. Survival of trout eggs would be improbable in the backwater habitat. This is perhaps the most important reason for the low numbers of trout in the area. In contrast, the flannelmouth sucker is well adapted to the silty conditions, having evolved in the historically turbid Colorado River.

Reproduction of fishes in the study area takes place in the spring or summer, with the exception of brown trout and mountain whitefish which spawn in late fall or early winter. Onset of spawning is controlled by water temperature and photoperiod (Andreasen and Barnes 1975) and stream discharge (Hynes 1970). Of the reproductive habits of the common fishes at the RBOSP site, only those of fathead minnow and mottled sculpin have been described to any extent. Spawning of mottled sculpin takes place in May or June (Hynes 1970; Bailey 1952) and for the fathead minnow in June and possibly extending through the summer (Hynes 1970). Both species deposit adhesive eggs on the underside of rocks or other suitable material. The males then guard the eggs from predation and/or siltation. Such adaptations contribute to the abundance of mottled sculpins in the study area and could possibly assist the fathead minnow in establishing itself in the area.

Information on reproductive habits of other common species is nonexistent or sketchy. The flannelmouth sucker is abundant in the study area and many other parts of the Colorado River drainage, but the reproductive biology of the species has not been reported in the literature. Data from the present study indicate that flannelmouth suckers reach sexual maturity when they are about 400 mm total length. Data from the 1975 fish studies suggested that spawning of flannelmouth suckers had taken place in June at water

temperatures of 12-13 C. Evidence from 1976 fish studies suggested that spawning occurred much earlier. The earlier spawning in 1976 was probably induced by a rapid rise in water temperatures as a result of a shorter snow-melt runoff period in 1976. Fecundity, or estimates of the total number of eggs contained in the ovaries, was estimated for flannelmouth suckers in 1975 and 1976 as 7,276 to 13,841 eggs, respectively. Fecundity appeared to be linearly correlated with the total length of fish.

Too few numbers of sexually mature bluehead suckers were taken at the RBOSP site to yield information of reproductive biology. However, Andreason and Barnes (1975) reported that bluehead suckers spawned from May through early July in the Weber River, Utah, at water temperatures of approximately 5-10 C. The preferred spawning habitat for the flannelmouth and bluehead sucker is probably relatively clear riffle areas where the eggs are partially buried in gravel during the spawning act (as with other members of the genus Catostomus, according to Hynes 1970).

The reproductive habits of the speckled dace, the most frequently captured species at the RBOSP site, have not been described in detail (Minckley 1973). Other members of the genus Rhinichthys sometimes build nests for egg deposition The preferred spawning habitat appears to be riffles (Minckley 1973).

Each successful fish species in the study area has its own spawning adaptations that ensure survival of eggs and young in the swift, turbid water environment. The adhesive eggs of the fathead minnow and mottled sculpin protect against displacement and the guarding males assist in keeping the eggs free of silt. The act of burying many of the deposited eggs by the suckers, and probably by the speckled dace, limits displacement by the current, and the riffle currents minimize siltation.

The interaction of fish with other biological groups in the environment is most obviously manifested in the feeding habits of the fishes. Food habit studies of major species at the RBOSP study area and information in the literature indicate that the indigenous species feed primarily on benthic invertebrates, especially immature insects of the family Chironomidae and of the orders Plecoptera, Ephemeroptera, and Trichoptera.

Although there is considerable overlap of feeding habits among the fishes, differences are great enough to prevent direct competition between species. Both the flannelmouth and bluehead suckers ingested immature insects. However, stomach contents of bluehead suckers, as well as the specially adapted mouth and intestine of this species, indicate a primarily herbivorous feeding mode; this species is thus classified as a primary consumer. Flannelmouth suckers feed largely on immature insects, and ingested significant amounts of plant material only in June and July.

Changes in fish diets with the seasons are brought about by food availability. For instance, the decrease in immature insects and increase in algae and plant material from spring to summer in flannelmouth sucker stomachs follow similar changes in the environment. Seasonal diet changes were also recorded for the mottled sculpin. Stoneflies of the genus Isoperla were important in the sculpin diet only in April, the only time they occurred in significant numbers in the benthos samples. Also, the abundance of hydropsychids in sculpin stomachs generally paralleled their abundance in the environment.

Diets also change with the size of fish of a given species; however, no attempt was made to quantify this change in the present study. One obvious case of diet change with increased fish size was seen in the present study; only mottled sculpins that were larger than 80 mm consumed fish. The most common food items in the White River fish stomachs were Chironomidae, Baetis and Ephemerella (Ephemeroptera), Hydropsyche (Trichoptera) and, to a lesser extent, Isoperla (Plecoptera).

Thus, the energy utilized by the fishes of the study area is obtained through several pathways. The primary pathway passes from allochthonous or autochthonous organic matter to immature insects to fish. A greater degree of complexity is introduced by the fact that aquatic insects exhibit a variety of feeding modes. The Ephemeroptera are primarily herbivorous, the Odonata and certain Chironomidae are carnivorous, the Plecoptera are omnivorous, and other are detritivorous. So, although fish are generally considered secondary consumers, they can also be considered primary, secondary, tertiary, or quaternary consumers; depending on the organisms they ingest and, in fact, they are mostly secondary consumers in White River.

III. GROUNDWATER HYDROLOGY AND WATER QUALITY

A total of 15 alluvial aquifer monitor holes have been completed. Eight of these holes encountered water when drilled and have had water with an average dissolved solids content of 780 mg/l since that time. The results of the alluvial monitoring program indicate that the major drainage systems have water-saturated alluvium and that in most of the minor drainage systems the alluvium is dry. In the major drainage sytems, the data indicate a seasonal trend in the water levels during the snowmelt runoff period and declining water levels the remainder of the year.

Average water quality in alluvial monitoring holes showed a 50 percent or greater probability of exceeding drinking water standards for cadmium, iron, lead, manganese, sulfate, and dissolved solids. Limiting constituents for beneficial use for rangeland animals are cadmium and lead. In the alluvial aquifer, in contrast to surface water and the soil shale aquifers, sulfate was directly related to sodium and bicarbonate. An inverse relationship was also shown between calcium and magnesium. The dominant controls on water quality however, were sodium, bicarbonate, and sulfate concentrations.

The drilling programs indicated two major oil shale aquifer systems to be present under Tract C-a. The upper aquifer system occurs in the vicinity of the Mahogany zone near the top of the oil shale interval. The lower aquifer system is about 600 feet below the upper aquifer and is associated with the R-3 zone and in some cases is as deep as the Blue marker. Both aquifer systems are artesian. With the exception of the northeast corner of Tract C-a, the upper aquifer system was a higher piezometric level than the lower aquifer system. Although quite variable from place to place, the aquifers each have an average thickness of about 220 feet. Both aquifers derive their permeability primarily from fractures and interconnected vugs.

A dual monitor hole completion was designed to isolate the aquifers in order to obtain water levels and water samples from one hole for the two different aquifers. This method of completion also allowed the tubing to be removed so

individual zones could be tested or pumped. Four upper aquifer pumping tests and four lower aquifer pumping tests were conducted. The effects of the upper aquifer pumping tests were primarily observed only in nearby holes. Each of the lower aquifer pumping tests generally affected all of the lower aquifer observation holes.

The long-term pumping tests allowed for the calculation of transmissivity and coefficients of storage at various monitoring holes located on and around the tract. The extrapolation of these values resulted in apparent transmissivities of 2,500 gpd/ft and 7,000 gpd/ft for the upper and lower aquifers, respectively. Based on anlysis of upper aquifer recoveries from pre lease core holes, the transmissivity was estimated to be about 3,000 gpd/ft. The transmissivity and coefficients of storage for the lower aquifer system are considered to be much more reliable than those for the upper aquifer system.

An analysis of the various pumping tests in both aquifer systems revealed an elongation of the cone of depression along the NNW-SSE axis. A comparison of the trends of the major fracture-joint sets on Tract C-a indicate three major directions. These are generally oriented NW-SE, NNE-SSE, and N-S. The directions are given in order of decreasing number of fracture and joint orientations. Therefore, a resultant preferred directional flow in these aquifers would be along the NNW-SSE as observed during the pumping test.

The deep aquifer monitoring program was initiated in December 1974. Early data collection consisted of measuring water levels. These were both static water levels and dynamic water levels as the result of the pumping program. The sampling program began in March 1975. For a period of six months, water samples were collected monthly and anlyzed for the constituents as outlined by the AOSS. Both aquifers have a downward gradient to the northeast. The upper aquifer has a much steeper gradient than the lower aquifer, approximately 150 ft/mi compared to 10 ft/mi. the piezometric levels intersect in the northeast corner of the tract and diverge toward the center of the basin. Thus northeast of the tract the lower aquifer has a higher piezometric level than the upper aquifer. The upper aquifer system has been found to have better water quality than the lower aquifer system. The average dissolved solids from all monitoring holes are approximately 905 mg/l and 1,075 mg/l for the upper and lower aquifers, respectively.

Generally, water quality in the upper and lower aquifers deteriorates downgradient. Interconnection of the upper and lower aquifers exists in the northeastern corner of the tract as shown by water quality data. The dominant control on water quality is the dissolution of nacholite in both of the aquifers.

A comparison of baseline water quality with standards for drinking water showed the upper aquifer exceeded drinking water standards more than 50 percent of the time for iron, lead, manganese, sulfate, and TDS. Water quality standards for range animals are exceeded for cadmium and lead in the upper aquifer. Lower aquifer water quality exceeds drinking water standards for cadmium, fluoride, lead, iron, manganese, sodium, and dissolved solids. Range animal use of lower aquifer water is limited by cadmium, fluoride, and lead concentrations.

The upper and lower aquifers show a direct correlation between sodium, bicarbonate, and dissolved solids. The above parameters, as a group, show an inverse correlation with calcium and magnesium. Sulfate in the lower aquifer is associated with sodium and bicarbonate, while in the upper it was associated with calcium and magnesium. Dissolution of nacholite and other minor evaporite minerals control water quality in the oil shale aquifers. Precipitation of calcium carbonate may be taking place in some areas as suggested by the high saturation index. Some random variation in the above mentioned areal trend are present, probably due to local structural or lithologic changes.

Time trends in the lower aquifer water quality were detected showing recovery from the leakage from the upper aquifer. Consistent time trends in quality were not present in the upper aquifer.

The major differences in water quality between ground water types can be differentiated by sodium, alkalinity, chloride, silica, fluoride, and sulfate. Discriminating equations were developed based on the above parameters and can be used for classifying unknown water samples as to similarity to each of the aquifers.

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